# AFFECT IN SPORTS, PHYSICAL ACTIVITY AND PHYSICAL EDUCATION

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# AFFECT IN SPORTS, PHYSICAL ACTIVITY AND PHYSICAL EDUCATION

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# Editorial: Affect in Sports, Physical Activity and Physical Education

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**Editorial on the Research Topic**

**Affect in Sports, Physical Activity and Physical Education**

Affect is a central theme of scientific inquiry in psychology, since its earliest debut. In recent years, substantial progress has been made to deepen our knowledge of how affective states (i.e., core affect, mood) and emotions influence our lives (Williams et al., 2018; Jekauc et al., 2019; Giurgiu et al., 2020). As sports, exercise, and physical activity represent behaviors with considerable properties related to affect, this additional knowledge across several scientific disciplines has the potential to stimulate research. Currently, emotions and affective states represent an important topic in sport and exercise psychology that has gained significant prominence in recent years. It has been speculated that there are three areas of application in the context of sport, exercise, and educational psychology.

First, the results of several studies suggest that affective constructs have a significant impact on motivation to adopt a physically active lifestyle (Jekauc and Brand, 2017). Accordingly, evidence seems to support a hypothesis showing that affective constructs are consistently related to physical activity (Rhodes et al., 2009; Rhodes and Kates, 2015). Second, emotions are supposed to have a considerable influence on performance in competitive sports (Kopp and Jekauc, 2018; Fritsch and Jekauc, 2020). For example, there is ample evidence that certain emotions, such as anxiety, can affect performance in important competitions (Woodman and Hardy, 2003), although the mechanisms of action are still unclear. Third, learning processes in physical education are also thought to be influenced by affective phenomena (Simonton et al., 2021). However, this last area of research is less well-explored.

The aim of this Research Topic was to investigate the relationship between affective processes and action in these three areas of application. In the context of this Research Topic, it became clear that the topic of emotions and affective processes plays a much greater role in research in competitive sports and exercise than in physical education. Eight papers in this Research Topic addressed aspects of exercise and physical activity, six papers addressed aspects of competitive sports, and unfortunately, no paper addressed aspects of physical education.

## EXERCISE PSYCHOLOGY

In the field of exercise psychology, affective processes are considered as determinants of physical activity. Depending on which paradigm a study is based on, affective processes play different roles and are assigned to different constructs. While in the context of the social cognitive approach affective processes are attributed to cognitive constructs such as affective attitudes or affective outcome expectancies (French et al., 2005; Conner et al., 2011), in the context of dual process theories affective processes are understood as determinants of the implicit processes of behavior control (Williams and Bohlen, 2019; Strobach et al., 2020). Several dozen affective constructs now exist that can be considered as determinants of physical activity. Stevens et al. attempted to bring some clarity and structure to the discussion of affective determinants in their narrative review. As the final product of this review, the authors adapt the Affect and Health Behavior Framework (Williams and Evans, 2014) for exercise behavior, with four main categories of affective constructs that aim to provide an organizing structure in which the many different affects and affect-related constructs in sport psychology can be located. This raises the question of whether affective constructs can be influenced as part of interventions to increase levels of physical activity. In a meta-analysis, Chen et al. found that affective constructs can indeed be effectively influenced by interventions to increase physical activity levels. Positive affective variables partially mediated intervention effects on physical activity, and both indirect and direct effects were significant, implying that other non-affective constructs besides affective variables play a role in driving health behaviors.

One such mechanism of how affective variables influence physical activity is habit formation. In their longitudinal study with many measurement time points, Weyland et al. found that positive affective states during exercise are significantly involved in the development of physical activity habits. Therefore, one strategy to promote health-related habits might be to promote positive affective states during exercise. Slawinska and Davis suggest that in addition to the actual affect experienced during exercise, recalled affect also has an influence on behavioral control, with the intensity of exercise and time playing a role in this process. In this context, Box and Petruzzello note that high-intensity interval exercise is one of the top trends in the fitness industry and this popularity is likely due to the affective processes during high-intensity exercise. Another potential affective determinant of physical activity in young adults is anticipated shame, which, however, was found to be an inconsistent predictor in Garn and Simonton's study. To explain motivation for physical activity and sedentary behavior, Stults-Kolehmainen et al. developed the WANT model (Wants and Aversions for Neuromuscular Tasks) based on findings from neurophysiological research, which postulates two unrelated dimensions (wants vs. aversion). To test the assumptions of this model, Stults-Kolehmainen et al.'s developed a questionnaire to measure these two dimensions as part of a second paper in this Research Topic. The results of psychometric analyses seem to confirm the assumptions of the WANT model and suggest good psychometric properties.

## SPORT PSYCHOLOGY

In the field of sport psychology, emotions can be considered as determinants of athletic performance. However, until now, clear evidence based on experimental research has been lacking. To address this research gap, Giles et al. addressed the research question of the extent to which approach-oriented emotions (i.e., anger) and avoidance-oriented emotions (e.g., fear) could be systematically manipulated by an intervention and the extent to which runners' performances could be influenced by the induced emotions. The results of the study confirmed the hypothesis that approach-related emotions could enhance runners' performance. In another study, Fritsch et al. investigated the situational factors influencing emotional expressive behavior in real table tennis matches. The results showed that the importance of the situation (e.g., big points) consistently influenced the expression of positive and negative emotions, whereas the controllability of the situation did not always influence the athletes' expressive behavior. In addition, the results of this study could not confirm the hypothesis that emotional expression behavior influences the probability of winning and losing the next point. In another study, Dong et al. found that systematic use of probiotics, such as *Bifidobacterium animalis* subsp. lactic BB-12, could significantly reduce cognitive and somatic anxiety and led to increased performance in young divers.

In addition to the question of how emotions arise in sport and what consequences they have for athletes' performance, it is very significant to investigate how emotions can be effectively regulated. One strategy of emotion regulation is self-distancing, which was shown to be an effective strategy for reducing aggressive behavior and negative affect in the study by Michel-Kröhler et al. Two other studies examined how specific emotions could be measured in the context of competitive sport. Rice et al. examined the psychometric properties of the Athletic Perceptions of Performance Scale when assessing athlete-specific guilt and shame in junior elite cricketers. The analyses largely confirmed that shame-proneness mediated the relationship between general and athlete-specific distress, whereas guilt-proneness was not a significant mediator. Finally, Han et al. examined the extent to which the mood profiles identified in many English-language studies could also be found in other cultural communities. The results of a study with participants from Singapore could confirm these six hypothesized mood profiles.

## CONCLUSION

In sport and exercise psychology, there is a growing awareness that emotions influence multiple processes such as motivation, performance, or learning, and thus have a significant impact on people's actions in a sport context. The contributions cover a wide range of exciting new questions, spanning from the emergence of emotions in competitive sports to the effects of affective states on habit formation. However, research in the area of physical education is comparatively scant and not represented at all within the scope of this Research Topic. Obviously, our Research Topic has not reached researchers in physical education and possibly such research is difficult and faces many formal obstacles in the context of schools. Notwithstanding these difficulties, research in the context of school sports is crucial to our understanding of emotional processes.

It is noteworthy that a variety of methods have been used in the contributions to this Research Topic, including correlational, longitudinal, and experimental designs that include behavioral and self-report measures. To reach the next level in the study of affective processes in the context of sport, it will probably be important to also include objective methods of affect capture such as skin conductance, heart rate, or hormone concentration in saliva. Encouragingly, we found that one meta-analysis, one narrative review, and three papers on the development of new measurement instruments to assess emotion-related constructs were authored. We see in these endeavors that new and innovative approaches to the study of emotional processes in the context of sport are being taken.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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# Mood Profiling in Singapore: Cross-Cultural Validation and Potential Applications of Mood Profile Clusters

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Mood profiling is a popular method of quantifying and classifying feeling states. Previous research has identified several novel mood profiles in predominantly Western English-speaking populations (Parsons-Smith et al., 2017), and replicated the findings in the domain of sport and exercise (Quartiroli et al., 2018; Terry and Parsons-Smith, 2019). The aim of the current study was to investigate if six hypothesized clusters of mood responses were evident in a population of English-speaking sport and non-sport participants in Singapore. A seeded k-means cluster analysis was applied to the mood responses of 1,444 participants (991 male, 440 female, 13 unspecified; aged 18–65 years) who completed the Brunel Mood Scale (BRUMS; Terry et al., 1999, 2003a). The six hypothesized mood profiles (i.e., iceberg, inverse Everest, inverse iceberg, shark fin, submerged, and surface profiles) were identified clearly. Chi-squared analyses showed unequal distribution of the profiles by gender, age group, ethnicity, education level, and sport participation. Findings support the cross-cultural generalizability of the six mood profiles in English-speaking sport and non-sport samples in Singapore and contribute to investigation into the antecedents, correlates, and consequences of each mood profile.

**Keywords: affect, emotion, cluster analysis, mood profiling, BRUMS**

## INTRODUCTION

Sport psychologists have long been interested in the study of mood and its relationship with performance. For the purpose of our investigation, mood is defined as "a set of feelings, ephemeral in nature, varying in intensity and duration, and usually involving more than one emotion" (Lane and Terry, 2000, p. 17). Morgan (1980) reported that mood responses were predictive of athletic performance and developed a mental health model proposing that positive mood is associated with psychological well-being and athletic success, whereas negative mood is associated with psychopathology and poor performance (Morgan, 1985). The notion that the *iceberg* profile, a pattern of mood responses characterized by above average vigor and below average tension, depression, anger, fatigue, and confusion, was the "test of champions" (Morgan, 1980) gained much traction and spawned a large body of research on the subject (see Rowley et al., 1995; Beedie et al., 2000). Research subsequently showed that the iceberg profile was the typical mood profile reported by athletes, successful or otherwise, and hence its predictive effectiveness may be more limited than previously claimed (Renger, 1993; Terry and Lane, 2000).

Athletic performance for some individuals is closely related to mood but this is not the case for other individuals (Totterdell, 1999; Lane and Chappell, 2001) and therefore the utility of mood profiling for predicting performance may rely on the individualized assessment of idiosyncratic mood-performance relationships (Terry, 1995). Other applications of mood profiling in sport include assessing risk of burnout by overtraining (Morgan et al., 1987), screening for risk of eating disorders (Terry and Galambos, 2004), quantifying the beneficial effects of music (Terry et al., 2020), and as a catalyst for discussion between practitioner and athlete to gain insights into performance and well-being (Terry, 1995).

In addition to the iceberg profile, other distinct mood profiles have been identified. The *inverse iceberg* profile, characterized by below average scores for vigor and above average scores for tension, depression, anger, fatigue, and confusion, has been shown to be associated with reduced performance (Budgett, 1998), higher occurrence of athletic injury (Galambos et al., 2005), and risk of mental health disorders (van Wijk et al., 2013). The *Everest* profile, a more prominent iceberg profile characterized by higher vigor scores, and lower tension, depression, anger, fatigue, and confusion scores, is anecdotally associated with superior performance (Terry, 1995).

More recent studies (Parsons-Smith et al., 2017; Quartiroli et al., 2018) have identified new profiles, referred to as the *inverse Everest*, *surface*, *shark fin*, and *submerged* profiles. As described by Parsons-Smith et al. (2017, pp. 4–5), the inverse Everest profile is characterized by low vigor scores, high scores for tension and fatigue, and very high scores for depression, anger, and confusion. The surface profile is characterized by average scores for all six mood dimensions. The shark fin profile is characterized by below average scores for tension, depression, anger, vigor, and confusion, combined with a high score for fatigue. The submerged profile is characterized by below average scores for all six mood dimensions.

To date, research on mood profile clusters has been limited largely to Western populations. In order to demonstrate the cross-cultural stability and generalizability of clusters, it is necessary to identify them in different cultures. Singapore is a multicultural society whose citizens are mainly of Asian descent, with the main ethnic groups being Chinese, Malay, and Indian. Singapore's multiculturalism is reflected in its official documents and public signs, which are available in English, Mandarin, Malay, and Tamil. English is the official language of the country, largely due to acculturation from previous British colonial rule; hence English serves as the official medium of instruction in schools and businesses (Tanzer et al., 1996). As such, the large majority of Singaporeans, especially those educated in the public schools since the 1980s, are fluent in the English language.

Our study had two aims: (1) To examine if mood profile clusters previously reported are also evident in the general Singapore English-speaking population; and (2) to examine the distribution of distinct mood profiles across various demographic variables of interest. Retrieving the hypothesized mood profile clusters in a Singaporean sample will provide further support for the validity and generalizability of these mood profiles, demonstrating their cross-cultural replicability. Mood profiling as an applied technique has considerable potential for practitioners to examine relationships between mood and various outcomes of interest in clinical as well as non-clinical settings. Clarification of the distribution of mood profiles in relation to various demographic variables may provide insights into the design and implementation of potential interventions and programs to better serve various segments of the Singaporean population. Results from this study set the stage for further research in Singapore to explore the practical, clinical, and theoretical implications of mood profiling.

## MATERIALS AND METHODS

### Participants

A total of 1,444 Singapore residents participated in the study (991 male, 440 female, 13 unspecified; age range: 18–65 years). The ethnic distribution of participants was 80.5% Chinese, 8.2% Malay, 8.2% Indian, and 2.1% other, which approximates the ethnic distribution of Singapore as a whole (Department of Statistics Singapore, 2018). All participants could read and write in English, which is the first language of most Singaporeans. A total of 65.4% ($n$ = 945) of respondents participated in sport either for leisure ($n$ = 514) or competitively ($n$ = 431). **Table 1** presents the sample demographics.

### Measures

Participants reported relevant demographic information (gender, age band, ethnicity, education level, sport participation, participation level) and completed a mood scale. Mood was assessed using the Brunel Mood Scale (BRUMS; Terry et al., 1999, 2003a), a 24-item scale of basic mood descriptors, in its original format with the recommended response timeframe of "How do you feel right now?" (Terry et al., 2005). Participants rated their responses on a five-point Likert scale (0 = *not at all*, 1 = *a little*, 2 = *moderately*, 3 = *quite a bit*, and 4 = *extremely*). The measure has six subscales (i.e., anger, confusion, depression, fatigue, tension, and vigor) each with four items, with total subscale scores ranging from 0 to 16. No total mood disturbance scores were calculated, as the focus of the study was on the profiles generated from the six subscale scores. The BRUMS has been validated across diverse cultures (e.g., Terry et al., 2003b; Zhang et al., 2014) and contexts (e.g., van Wijk et al., 2013; Sties et al., 2014). Subscales show good internal consistency, with Cronbach alpha coefficients ranging from 0.74 to 0.90 (Terry et al., 1999). Cross-cultural assessment of the BRUMS has supported it as a valid measure of mood in the Singaporean context, and local norms are available (Han et al., 2019).

### Procedure

Two methods of data collection were used to recruit English-speaking Singaporean participants. First, a link to an online version of the BRUMS, hosted on the university's eResearch

**TABLE 1 |** Sample demographics ($N$ = 1,444).

| Source | *n* | % |
|---|---|---|
| **Gender** | | |
| Male | 991 | 68.6 |
| Female | 440 | 30.5 |
| Unspecified | 13 | <1 |
| **Age band** | | |
| 18–21 | 507 | 35.1 |
| 22–25 | 256 | 17.7 |
| 26–30 | 336 | 23.3 |
| 31–35 | 140 | 9.7 |
| 36–40 | 75 | 5.2 |
| 41–45 | 34 | 2.4 |
| 46–50 | 22 | 1.5 |
| 51–55 | 24 | 1.7 |
| >55 | 36 | 2.5 |
| Unspecified | 14 | 1.0 |
| **Age group** | | |
| ≤25 years | 763 | 52.8 |
| 26+ years | 667 | 46.2 |
| Unspecified | 14 | 1.0 |
| **Ethnicity** | | |
| Chinese | 1163 | 80.5 |
| Malay | 119 | 8.2 |
| Indian | 118 | 8.2 |
| Other | 31 | 2.1 |
| Unspecified | 13 | <1 |
| **Education level** | | |
| Primary/Secondary | 70 | 4.8 |
| JC/IB/Poly/ITE# | 873 | 60.5 |
| University | 370 | 25.6 |
| Postgraduate | 93 | 6.4 |
| Other | 18 | 1.2 |
| Unspecified | 20 | 1.4 |
| **Sport participation** | | |
| Sport | 954 | 66.1 |
| Non-sport | 476 | 33.0 |
| Unspecified | 14 | 1.0 |
| **Participation level** | | |
| Recreational | 514 | 35.6 |
| School/Club | 339 | 23.5 |
| Regional/International | 92 | 6.4 |
| Unspecified | 9 | <1 |

*[#] JC, Junior College; IB, International Baccalaureate; Poly, Polytechnic Diploma; ITE, Institute of Technical Education Certification.*

Survey System was distributed to a sample of Singapore residents using snowball sampling and assistance from the Singapore Sport Institute, which produced a sample of 695 respondents (48.1% of the total sample). A second group of participants was recruited at random from a range of organizations (e.g., schools and workplaces) who completed a paper-and-pencil version of the BRUMS. Participants were informed they were part of a research study aimed at validating a mood scale for use in Singapore, and their informed consent was sought prior to participation in the study. This study was conducted in accordance with the Australian Code for the Responsible Conduct of Research. The protocol was approved by the Human Research Ethics Committee at the University of Southern Queensland (USQ; approval number: H17REA143).

## Data Screening

A total of 13 cases with missing values for the BRUMS were excluded from the analysis. Data were screened for compliance with the assumptions of univariate and multivariate normality. Like previous samples (Parsons-Smith et al., 2017), significant univariate non-normality was found in some subscales (e.g., depression, anger, and tension), consistent with typical mood subscale distributions. Negative mood scores tended toward higher numbers at the lower end, and lower numbers at the upper end (Terry et al., 1999). The frequency distributions for skewness and kurtosis were examined and it was concluded that deviations from normal distribution were unlikely to make a substantive difference to the analyses, thus no data were removed. A total of 45 multivariate outliers were identified according to a Mahalanobis distance statistic at $p < 0.001$. A case-by-case visual inspection suggested that response patterns were plausible. Given this, all outliers were retained, leaving a final sample of 1,444 respondents.

# RESULTS

The results of this study are presented in three parts–cluster analysis, discriminant function analysis, and distribution of mood profiles by demographic variables.

## Cluster Analysis

The objective of cluster analysis was described by Anderberg (2014) as the separation of data units or variables into groups (i.e., clusters), such that the elements within a cluster have a high degree of natural association and the clusters are relatively distinct from one another. The Statistical Package for Social Sciences, version 25 was used to conduct the cluster analysis, specifically $k$-means clustering (MacQueen, 1967), a method used to automatically split a dataset into a specified number of clusters. Using raw score cluster centroids from Quartiroli et al. (2018) (see **Table 2**), a seeded $k$-means cluster analysis with a prescribed six-cluster solution was run on the whole sample, and then separated by sport and non-sport participants. The six clusters previously identified by Parsons-Smith et al. (2017) and Quartiroli et al. (2018), referred to as the iceberg profile (23.3% of the sample), inverse Everest profile (4.8%), inverse iceberg profile (12.2%), shark fin profile (16.6%), submerged profile (27.3%), and surface profile (15.9%), were clearly identified in the present sample. Descriptive statistics of the six-cluster solution are presented in **Table 3**, presented as $T$-scores derived from local norms provided by Han et al. (2019). The distribution of clusters is similar to that reported by Parsons-Smith et al. (2017). Visual representations of the six mood profiles are shown in **Figure 1**.

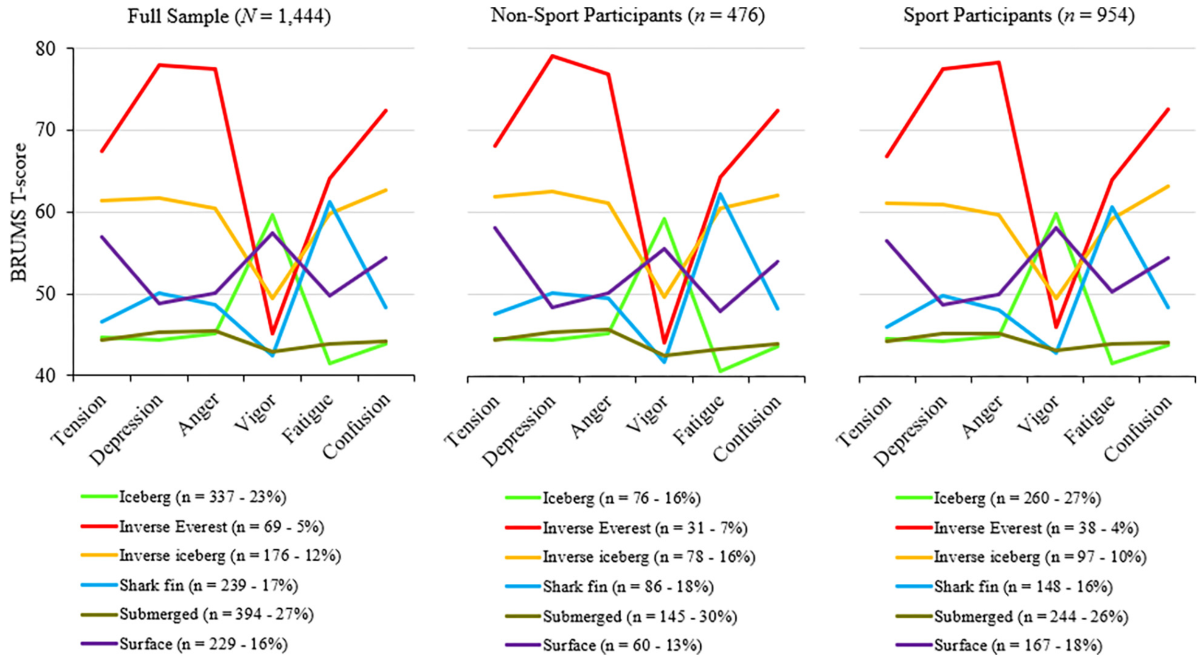


**FIGURE 1 |** Visual representations of the six mood profiles.

**TABLE 2 |** Raw score centroids used in the cluster analysis.

| | Cluster | | | | | |
|---|---|---|---|---|---|---|
| **Mood dimension** | **1** | **2** | **3** | **4** | **5** | **6** |
| Tension | 1.15 | 10.42 | 6.34 | 1.75 | 1.29 | 4.58 |
| Depression | 0.25 | 11.19 | 5.11 | 1.26 | 0.59 | 1.69 |
| Anger | 0.41 | 10.23 | 4.52 | 0.95 | 0.48 | 2.26 |
| Vigor | 10.62 | 4.69 | 5.98 | 4.14 | 4.72 | 9.10 |
| Fatigue | 2.39 | 11.83 | 8.59 | 9.97 | 2.91 | 4.76 |
| Confusion | 0.54 | 10.75 | 5.84 | 1.32 | 0.90 | 3.27 |

*1 = iceberg, 2 = inverse Everest, 3 = inverse iceberg, 4 = shark fin, 5 = submerged, 6 = surface.*

## Discriminant Function Analysis

To explore the clusters further, a *post hoc* simultaneous multiple discriminant function analysis (DFA) was conducted to evaluate how well the clusters were classified. DFA predicts group membership in naturally occurring groups, based on predictor variables, and is not affected by unequal sample sizes (Tabachnick and Fidell, 2013). DFA is a two-step statistical procedure which involves significance testing of discriminant functions, followed by a computational process of classification. The ratio of cases to independent variables was 241 to 1, which far exceeds the recommended minimum ratio of 20 to 1. The DFA identified five functions accounting for 100% of the variance with the first three functions accounting for 98.2% of the variance (**Table 4**). A single-factor MANOVA was conducted to assess the between-cluster differences in subscale scores, which showed a significant omnibus effect, Wilks' $\lambda = 0.031$, $F(30,5734) = 266.04$ $p < 0.001$, partial $\eta^2 = 0.502$. Using a Bonferroni-adjusted alpha level of 0.008, significant univariate effects were confirmed for all mood dimensions: tension, $F(5,1438) = 352.14$, $p < 0.001$, partial $\eta^2 = 0.550$; depression, $F(5,1438) = 609.78$, $p < 0.001$, partial $\eta^2 = 0.680$; anger, $F(5,1438) = 444.98$, $p < 0.001$, partial $\eta^2 = 0.607$; vigor, $F(5,1438) = 347.85$, $p < 0.001$, partial $\eta^2 = 0.547$; fatigue, $F(5,1438) = 667.34$, $p < 0.001$, partial $\eta^2 = 0.699$; confusion, $F(5,1438) = 539.79$, $p < 0.001$, partial $\eta^2 = 0.652$.

Mood dimensions strongly associated with Function 1 were high depression, fatigue, confusion, anger, and tension. Function 2 identified high vigor and tension, and low fatigue. Function 3 identified low depression and anger, and high fatigue and vigor. **Table 5** lists all five discriminant functions. The findings suggest that the distribution overlap was small and the functions discriminated between clusters with a very high degree of accuracy, with correct classifications for the iceberg profile at 99.1%, inverse iceberg profile at 89.9%, inverse iceberg at 94.3%, shark fin profile at 95.4%, submerged profile at 99.5%, and surface profile at 91.7% (see **Table 6**). It was found that 96.4% of the cases were correctly reclassified back into the original clusters, which is markedly higher than the minimum classification accuracy rate of 44.9% (i.e., the proportional by chance accuracy +25%).

## Demographic Influences on Mood Responses

Single-factor MANOVAs were used to provide an initial assessment of the influence of demographic variables on mood responses. Participants in the unspecified and "other" categories were excluded from these analyses. Significant multivariate variability was found for gender, age group,

**TABLE 3 |** Descriptive statistics of the 6-cluster solution (*N* = 1,444).

| | Iceberg (*n* = 337, 23.3%) | | | Inverse Everest (*n* = 69, 4.8%) | | |
|---|---|---|---|---|---|---|
| **Mood dimension** | ***M*** | ***SD*** | **95% CI** | ***M*** | ***SD*** | **95% CI** |
| Tension | 44.65 | 4.37 | [44.18, 45.12] | 67.40 | 12.35 | [64.44, 70.37] |
| Depression | 44.30 | 2.87 | [44.00, 44.61] | 78.06 | 7.97 | [76.15, 79.98] |
| Anger | 45.08 | 3.42 | [44.72, 45.45] | 77.52 | 11.55 | [74.75, 80.30] |
| Vigor | 59.70 | 6.04 | [59.05, 60.35] | 45.20 | 9.49 | [42.92, 47.48] |
| Fatigue | 41.43 | 4.97 | [40.89, 41.96] | 64.10 | 6.97 | [62.43, 65.78] |
| Confusion | 43.83 | 4.13 | [43.39, 44.27] | 72.42 | 8.76 | [70.31, 74.52] |
| | **Inverse iceberg (*n* = 176, 12.2%)** | | | **Shark fin (*n* = 239, 16.6%)** | | |
| **Mood dimension** | ***M*** | ***SD*** | **95% CI** | ***M*** | ***SD*** | **95% CI** |
| Tension | 61.40 | 9.20 | [60.03, 62.77] | 46.64 | 5.90 | [45.89, 47.39] |
| Depression | 61.69 | 8.17 | [60.47, 62.90] | 50.06 | 7.30 | [49.13, 50.99] |
| Anger | 60.38 | 9.58 | [58.95, 61.80] | 48.65 | 6.41 | [47.84, 49.47] |
| Vigor | 49.52 | 8.14 | [48.31, 50.73] | 42.48 | 6.94 | [41.59, 43.36] |
| Fatigue | 59.78 | 7.09 | [58.72, 60.83] | 61.27 | 5.28 | [60.60, 61.94] |
| Confusion | 62.68 | 8.22 | [61.46, 63.90] | 48.35 | 6.41 | [47.53, 49.17] |
| | **Submerged (*n* = 394, 27.3%)** | | | **Surface (*n* = 229, 15.9%)** | | |
| **Mood dimension** | ***M*** | ***SD*** | **95% CI** | ***M*** | ***SD*** | **95% CI** |
| Tension | 44.43 | 4.65 | [43.97, 44.89] | 56.96 | 8.50 | [55.85, 58.07] |
| Depression | 45.38 | 4.16 | [44.96, 45.79] | 48.84 | 5.92 | [48.07, 49.61] |
| Anger | 45.54 | 4.08 | [45.13, 45.94] | 50.05 | 7.03 | [49.14, 50.97] |
| Vigor | 42.99 | 5.72 | [42.42, 43.55] | 57.46 | 6.94 | [56.56, 58.36] |
| Fatigue | 43.80 | 4.83 | [43.32, 44.27] | 49.77 | 5.63 | [49.03, 50.50] |
| Confusion | 44.17 | 4.54 | [43.72, 44.62] | 54.33 | 6.45 | [53.49, 55.17] |

*Table presents T-scores converted from raw scores with reference to local norms reported by Han et al., 2019.*

ethnicity, education level, and sport participation (see **Table 7**) but not for participation level, which was excluded from subsequent analyses. Univariate analyses identified many significant between-group differences. Females reported higher scores for anger, confusion, depression, and fatigue, and lower scores for vigor, compared to males. Younger participants reported higher scores for confusion and tension than older participants. Malay participants reported higher anger, confusion, depression, fatigue, and tension scores than Chinese participants. Participants with up to secondary education reported lower scores for fatigue and higher scores for vigor than those with a university education. Those involved in sport reported lower scores for anger, depression, fatigue, and tension, and higher scores for vigor, than those not involved in sport.

## Distribution of Mood Profiles by Demographic Variable

Chi-squared tests were used to assess the distribution of mood profile clusters according to the demographic variables of interest. Significant variations in distribution were evident (see **Table 8**), for gender, age group, ethnicity, level of education, and sport participation. Adjusted residuals were used to investigate the source of these differences. The distribution of mood profiles by the various demographic variables are elaborated below.

### Gender

The distribution of the six mood profiles varied significantly by gender for all profiles. Males were over-represented in the iceberg, submerged, and surface profiles, whereas females were over-represented in the inverse Everest, inverse iceberg, and shark fin profiles, consistent with the findings of Parsons-Smith et al. (2017) and Quartiroli et al. (2018).

### Age Group

The distribution of inverse Everest, shark fin, and submerged profiles was independent of age group. Younger participants (≤25 years) were over-represented

**TABLE 4 |** Discriminant functions (*N* = 1,444).

| Discriminant function | Eigenvalue | % of variance | Cumulative% | Canonical correlation |
|---|---|---|---|---|
| 1 | 6.373 | 74.2 | 74.2 | 0.930 |
| 2 | 1.551 | 18.1 | 92.3 | 0.780 |
| 3 | 0.507 | 5.9 | 98.2 | 0.580 |
| 4 | 0.151 | 1.8 | 100.0 | 0.363 |
| 5 | 0.003 | 0.0 | 100.0 | 0.055 |

**TABLE 5 |** Structure matrix (*N* = 1,444).

| | Discriminant function | | | | |
|---|---|---|---|---|---|
| **Mood dimension** | **1** | **2** | **3** | **4** | **5** |
| Tension | 0.388 | 0.349 | −0.030 | −0.701* | 0.079 |
| Depression | 0.558* | 0.091 | −0.411 | 0.509 | −0.445 |
| Anger | 0.469 | 0.165 | −0.407 | 0.371 | 0.662* |
| Vigor | −0.104 | 0.808* | 0.473 | 0.302 | 0.137 |
| Fatigue | 0.529 | −0.417 | 0.720* | 0.139 | 0.088 |
| Confusion | 0.520* | 0.282 | −0.117 | −0.376 | −0.311 |

**Largest absolute correlation between each variable and any discriminant function.*

**TABLE 6 |** Cluster classifications (*N* = 1,444).

| | Cluster | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Cluster** | **1** | **2** | **3** | **4** | **5** | **6** | ***n*** | **%** |
| Iceberg | 334 | 0 | 0 | 0 | 3 | 0 | 337 | 99.1 |
| Inverse Everest | 0 | 62 | 7 | 0 | 0 | 0 | 69 | 89.9 |
| Inverse iceberg | 0 | 0 | 166 | 8 | 0 | 2 | 176 | 94.3 |
| Shark fin | 0 | 0 | 5 | 228 | 6 | 0 | 239 | 95.4 |
| Submerged | 1 | 0 | 0 | 0 | 392 | 1 | 394 | 99.5 |
| Surface | 11 | 0 | 2 | 0 | 6 | 210 | 229 | 91.7 |

*1 = iceberg, 2 = inverse Everest, 3 = inverse iceberg, 4 = shark fin, 5 = submerged, 6 = surface.*

**TABLE 7 |** MANOVA of BRUMS subscales by demographic variables.

| Source | Tension | | Depression | | Anger | | Vigor | | Fatigue | | Confusion | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| **Gender $F(6, 1424) = 17.52^{\dagger}$** | | | | | | | | | | | | |
| Male ($n$ = 991) | 49.63 | 9.74 | $48.57^{\dagger}$ | 8.89 | $48.84^{\dagger}$ | 8.76 | $50.99^{\dagger}$ | 10.00 | $48.69^{\dagger}$ | 9.45 | $49.27^{\dagger}$ | 9.25 |
| Female ($n$ = 440) | 50.89 | 10.60 | 53.19 | 11.57 | 52.64 | 12.00 | 47.96 | 9.68 | 52.90 | 10.59 | 51.67 | 11.39 |
| **Age group $F(6, 1423) = 11.54^{\dagger}$** | | | | | | | | | | | | |
| ≤25 years ($n$ = 763) | $51.35^{\dagger}$ | 10.82 | 49.96 | 9.75 | 49.63 | 9.44 | 49.78 | 10.15 | 50.61 | 9.95 | $50.91^{\dagger}$ | 10.21 |
| 26+ years ($n$ = 667) | 48.50 | 8.79 | 50.04 | 10.33 | 50.43 | 10.64 | 50.35 | 9.80 | 49.27 | 10.03 | 48.99 | 9.70 |
| **Ethnicity $F(12, 2784) = 6.43^{\dagger}$** | | | | | | | | | | | | |
| Chinese[a] ($n$ = 1,163) | 49.57 | 9.73 | 49.42 | 9.45 | 49.43 | 9.44 | $49.57^{*c}$ | 9.82 | 49.88 | 9.75 | 49.68 | 9.72 |
| Malay[b] ($n$ = 119) | $53.89^{\dagger a}$ | 11.35 | $54.81^{\dagger a}$ | 12.35 | $55.00^{\dagger a}$ | 12.70 | 51.15 | 10.58 | $53.95^{\dagger ac}$ | 11.19 | $53.63^{\dagger a}$ | 11.82 |
| Indian[c] ($n$ = 118) | 51.56 | 11.43 | 51.46 | 11.77 | $51.17^{*b}$ | 11.36 | 53.03 | 10.58 | 47.94 | 10.34 | 50.34 | 10.74 |
| **Level of education $F(18, 3951) = 4.52^{\dagger}$** | | | | | | | | | | | | |
| Primary/Secondary[a] ($n$ = 70) | 50.29 | 9.88 | 50.04 | 9.92 | 50.03 | 9.17 | $54.75^{*b}$ | 10.56 | $45.92^{*bc}$ | 9.08 | 48.71 | 8.87 |
| JC/IB/Poly/ITE[#b] ($n$ = 873) | 50.82 | 10.44 | 49.56 | 9.61 | 49.60 | 9.73 | 50.12 | 9.97 | 50.20 | 10.05 | 50.44 | 10.01 |
| University[c] ($n$ = 370) | 48.86 | 9.35 | 51.12 | 10.81 | 50.76 | 10.76 | $48.67^{\dagger a}$ | 9.63 | 50.71 | 10.23 | 49.61 | 10.39 |
| Postgraduate[d] ($n$ = 93) | 48.09 | 8.49 | 49.35 | 10.11 | 50.35 | 10.31 | 50.88 | 10.12 | 48.72 | 9.13 | 49.09 | 9.47 |
| **Sport participation $F(6, 1423) = 8.86^{\dagger}$** | | | | | | | | | | | | |
| Sport ($n$ = 954) | $49.41^{*}$ | 9.48 | $49.20^{\dagger}$ | 9.33 | $49.27^{\dagger}$ | 9.31 | $51.07^{\dagger}$ | 10.07 | $49.43^{*}$ | 9.58 | 49.61 | 9.73 |
| Non-sport ($n$ = 476) | 51.22 | 10.96 | 51.52 | 11.08 | 51.46 | 11.20 | 47.99 | 9.52 | 51.11 | 10.74 | 50.81 | 10.54 |

*Table presents T-scores converted from raw scores with reference to local norms reported by Han et al., 2019. [#]JC = Junior College, IB = International Baccalaureate, Poly = Polytechnic Diploma, ITE = Institute of Technical Education Certification. *$p < 0.008$, $^{\dagger}p < 0.001$.*

**TABLE 8 |** Distribution of clusters by demographic variables.

| Source | Cluster | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | % | 2 | % | 3 | % | 4 | % | 5 | % | 6 | % |
| **Gender $\chi^2(5, 1431) = 80.81^{\dagger}$** | | | | | | | | | | | | |
| Male ($n$ = 991) | $256^{\S+}$ | 25.8 | $31^{\dagger-}$ | 3.1 | $94^{\dagger-}$ | 9.5 | $137^{\dagger-}$ | 13.8 | $285^{*+}$ | 28.8 | $188^{\dagger+}$ | 19.0 |
| Female ($n$ = 440) | $80^{\S-}$ | 18.2 | $38^{\dagger+}$ | 8.6 | $81^{\dagger+}$ | 18.4 | $97^{\dagger+}$ | 22.0 | $104^{*-}$ | 23.6 | $40^{\dagger-}$ | 9.1 |
| **Age group $\chi^2(5, 1430) = 25.78^{\dagger}$** | | | | | | | | | | | | |
| ≤25 years ($n$ = 763) | $148^{\dagger-}$ | 19.4 | 32 | 4.2 | $110^{\S+}$ | 14.4 | 127 | 16.6 | 205 | 26.9 | $141^{\S+}$ | 18.5 |
| 26+ years ($n$ = 667) | $187^{\dagger+}$ | 28.0 | 37 | 5.5 | $65^{\S-}$ | 9.7 | 107 | 16.0 | 184 | 27.6 | $87^{\S-}$ | 13.0 |
| **Ethnicity $\chi^2(10, 1400) = 38.49^{\dagger}$** | | | | | | | | | | | | |
| Chinese ($n$ = 1,163) | 266 | 22.9 | $46^{\S-}$ | 4.0 | $131^{\S-}$ | 11.3 | 200 | 17.2 | $335^{\S+}$ | 28.8 | 185 | 15.9 |
| Malay ($n$ = 119) | 24 | 20.2 | $14^{\S+}$ | 11.8 | $25^{\S+}$ | 21.0 | 18 | 15.1 | $18^{\S-}$ | 15.1 | 20 | 16.8 |
| Indian ($n$ = 118) | 36 | 30.5 | 7 | 5.9 | 18 | 15.3 | 12 | 10.2 | 26 | 22.0 | 19 | 16.1 |
| **Level of education $\chi^2(15, 1406) = 39.77^{\dagger}$** | | | | | | | | | | | | |
| Primary/Secondary ($n$ = 70) | $23^{*+}$ | 32.9 | 3 | 4.3 | 4 | 5.7 | $5^{*-}$ | 7.1 | 16 | 22.9 | $19^{\S+}$ | 27.1 |
| JC/IB/Poly/ITE[#] ($n$ = 873) | 189 | 21.6 | 37 | 4.2 | 112 | 12.8 | 139 | 15.9 | 237 | 27.1 | $159^{\S+}$ | 18.2 |
| University ($n$ = 370) | 87 | 23.5 | 24 | 6.5 | 46 | 12.4 | $76^{*+}$ | 20.5 | 102 | 27.6 | $35^{\dagger-}$ | 9.5 |
| Postgraduate ($n$ = 93) | 28 | 30.1 | 5 | 5.4 | 9 | 9.7 | 11 | 11.8 | 28 | 30.1 | 12 | 12.9 |
| **Sport participation $\chi^2(5, 1430) = 40.32^{\dagger}$** | | | | | | | | | | | | |
| Sport ($n$ = 954) | $260^{\dagger+}$ | 27.3 | $38^{*-}$ | 4.0 | $97^{\dagger-}$ | 10.2 | 148 | 15.5 | $244^{*-}$ | 25.6 | $167^{*+}$ | 17.5 |
| Non-sport ($n$ = 476) | $76^{\dagger-}$ | 16.0 | $31^{*+}$ | 6.5 | $78^{\dagger+}$ | 16.4 | 86 | 18.1 | $145^{*+}$ | 30.5 | $60^{*-}$ | 12.6 |

*1 = iceberg, 2 = inverse Everest, 3 = inverse iceberg, 4 = shark fin, 5 = submerged, 6 = surface. [#]JC = Junior College, IB = International Baccalaureate, Poly = Polytechnic Diploma, ITE = Institute of Technical Education Certification. *$p < 0.05$, $^{\S}p < 0.01$, $^{\dagger}p < 0.001$. $^{+}$over-represented, $^{-}$under-represented.*

in the inverse iceberg and surface profiles and under-represented for the iceberg profile. Older participants (26+ years) were over-represented in the iceberg profile and under-represented in the inverse iceberg and surface profiles.

## Ethnicity

The distribution of iceberg, shark fin, and surface profiles was independent of ethnicity. Chinese Singaporeans were over-represented in the submerged profile and under-represented in the inverse Everest and inverse iceberg profiles. Malay

Singaporeans were over-represented in inverse Everest and inverse iceberg profiles and under-represented in the submerged profile.

### Level of Education

The distribution of the inverse Everest, inverse iceberg, and submerged profiles was independent of level of education. Participants with secondary school or below level of education were over-represented in the iceberg and surface profiles and under-represented in the shark fin profile. Participants with pre-university education (JC/IB/Poly/ITE) were over-represented in the surface profile, whereas those with a university education were over-represented in the shark fin profile and under-represented in the surface profile.

### Sport Participation

The distribution for the shark fin profile was independent of sport participation. Those who participated in sport were over-represented in the iceberg and surface profiles and under-represented in the inverse Everest, inverse iceberg, and submerged profiles. Those who did not participate in sport were over-represented in the inverse Everest, inverse iceberg, and submerged profiles and under-represented in the iceberg and surface profiles.

## DISCUSSION

Six mood profile clusters previously identified by Parsons-Smith et al. (2017) and Quartiroli et al. (2018), referred to as the iceberg, inverse iceberg, inverse Everest, shark fin, submerged, and surface profiles, were clearly retrieved among our sample of Singaporean participants, showing a similar structure matrix.

Support for the cross-cultural generalizability of these mood profiles makes a significant contribution to the literature on mood profiling and, more specifically, to the validation of the BRUMS as a tool for mood profiling in Singapore. The identification of associations between demographic variables and the incidence of mood profiles across multiple studies provides support for the use of mood profiling for various purposes, ranging from screening or monitoring of mental health to providing a tool to predict performance or other outcome variables of interest. Our findings enhance understanding of the association between demographic variables and mood profiles and may serve as a guide for practitioners and policy makers in the design of potential interventions to promote well-being among general as well as clinical populations.

A noteworthy finding of our study was that men were over-represented in the more positive iceberg profile whereas females were over-represented in the more negative inverse Everest, inverse iceberg, and shark fin profiles. There are several possible explanations for this gender difference. First, it has been reported that men and women regulate mood differently. For example, women are more likely to ruminate that men, which may influence their reported mood (Nolen-Hoeksema and Jackson, 2001). Second, there is a gender difference in hormonal activity (e.g., premenstrual syndrome, postnatal depression, menopause; Halbreich and Kahn, 2001) which may make some women more prone to negative moods. Third, it has been reported that women are more likely than men to report feeling depressed, sad, anxious, or nervous (American Psychological Association, 2012b), potentially explaining why women were over-represented in the more negative mood profiles. Finally, males are often taught from a young age to inhibit expression of emotion to a greater extent than females (Underwood et al., 1992), which may explain why males were over-represented for the submerged profile which has low scores on all six dimensions of mood.

In relation to age group, younger participants were under-represented while older participants were over-represented for the iceberg profile, whereas the reverse was true for the inverse iceberg profile. This is similar to trends identified in previous investigations of the age-related incidence of mood profile clusters (Parsons-Smith et al., 2017; Quartiroli et al., 2018). Interestingly, the age of onset of mood disorders is typically around the mid-20s (Kessler et al., 2007) and data from the *Stress in America* survey showed younger people report higher stress levels than older generations and also report that they do not manage it well (American Psychological Association, 2012a). These age-related trends in mood responses are worthy of further investigation in a Singaporean context.

With regard to ethnicity, our findings showed a higher incidence of negative mood profiles (inverse Everest, inverse iceberg) among Malay Singaporeans and a lower incidence among Chinese Singaporeans. Previous studies have found differences in health status as well as variations in the occurrence of mood disorders according to ethnicity (Johnson-Lawrence et al., 2013). Further investigation of ethnic differences in mood is warranted among the Singaporean population, perhaps by mapping the incidence of negative mood profiles in our dataset to the incidence of mental health disorders at the national level. Such investigations would further inform policy makers and practitioners on potential preventive or protective measures as well as interventions for the vulnerable groups.

There were few significant variations in the distribution of mood profiles related to level of education, although the relatively small number of participants in the primary/secondary and postgraduate education groups should be noted. Previous literature suggests that level of education and socioeconomic status may have an influence on the mental health of individuals (Hudson, 2005; Eid et al., 2013) and therefore the relationship between education level and mood profiles might provide the focus for future investigations in a Singaporean context.

A significant finding from our study relates to the distribution of mood profile clusters in relation to participation in sport. Our findings showed a clear association between sport participation and mood responses. Those engaged in sport were over-represented in the positive iceberg mood profile and under-represented in the more negative inverse Everest, inverse iceberg, and submerged profiles. This association between sport participation and positive mood profiles might be related to the positive effects of sport on mood or the effects of mood on physical functioning (Morgan, 1985; Beedie et al., 2000; Terry and Lane, 2000), although the direction of effects cannot be ascertained in our study due to its correlational design. The study also found that a lack of participation in sport was associated with experiencing negative moods, as evident in the over-representation of the inverse Everest (the most negative profile, characterized by high scores for tension and fatigue, combined with very high scores for depression, anger, and confusion, and perhaps indicative of psychopathology), inverse iceberg, and submerged profiles.

Research has increasingly shown physical activity to be an effective intervention to promote physical and psychological benefits for both healthy and clinical populations (Penedo and Dahn, 2005; Thøgersen-Ntoumani et al., 2005; Biddle and Asare, 2011) and our results are certainly consistent with that burgeoning evidence base. Practitioners can be confident in the potential for sport and other forms of physical activity to be effective interventions to enhance mood and health, and the findings from our study can be used to inform health programs targeted at the different demographic groups. Given the inherent benefits of physical activity on mood and well-being, future studies could adopt experimental designs to evaluate the effectiveness of specific interventions (e.g., music listening; Terry et al., 2020) used to encourage and maintain participation in physical activity, with mood profiling used to evaluate the efficacy of interventions for promoting positive moods.

Despite our sample size of 1,444 participants, when participants were distributed across the six mood profiles the number of participants in some cells was very small (see **Table 8**). We acknowledge this as a limitation of our study and hence some findings, particularly those related to ethnicity and education level, should be treated with caution. Some of the less frequently reported profiles, notably the inverse Everest profile which was reported by fewer than 5% of participants, would require a much larger overall sample for detailed exploration. Larger and/or more targeted samples would allow researchers to investigate if certain profile types, especially those with a negative orientation, could predict physical or mental health deficits that might signal the need for detailed follow-up or intervention. The lack of planned follow-up with respondents reporting extremely negative mood profiles was another limitation, given that only email addresses were recorded, which participants could decline to provide. Future studies should consider carefully the kind of contact information to be collected, inform participants of potential follow-ups, and provide them a brief mood report as well as avenues for assistance if required.

In summary, when the previous validation of the BRUMS for use in a Singaporean context (Han et al., 2019) is considered in tandem with the replication of mood profiles in the present study, many potential applications of mood profiling are feasible. The mood profile clusters identified provide local practitioners with a way to better interpret BRUMS test scores. The utility and meaningfulness of mood profiles will increase further once associations are established with objective measures of performance, behavioral outcomes or mental health indicators. Such knowledge would inform practitioners how to use mood profiling more effectively in clinical and non-clinical settings. For example, practitioners could use mood profiling as a method to help individuals and teams to build a stronger understanding of whether certain mood profile types facilitate or debilitate performance, especially in occupations and work conditions that are demanding or high-risk, such as military environments, law enforcement, elite sport, aviation, and so on. There is also the possibility of using the BRUMS as a screening or monitoring tool for mental health purposes, once the therapeutic meaningfulness of each of the six mood profiles is established.

## CONCLUSION

The findings of the current study provide evidence that the mood profile clusters previously reported by Parsons-Smith et al. (2017) and Quartiroli et al. (2018) are also evident in the English-speaking Singaporean resident population, confirming the cross-cultural replicability of the clusters. The current study raises many research questions for future investigation that relate to the antecedents, correlates, and consequences of the six mood profile clusters, and how mood profiling can be used to, for example, predict performance outcomes or monitor mental health status. Results from this study set the stage for further research in Singapore to explore the practical, clinical, and theoretical implications of mood profiling.

## DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request from the corresponding author.

## ETHICS STATEMENT

This study involving human participants was reviewed and approved by the Human Research Ethics Committee at the University of Southern Queensland (approval number: H17REA143). The participants provided informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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# When Anger Motivates: Approach States Selectively Influence Running Performance

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Emotional states are thought to influence athletic performance. Emotions characterized by high arousal enhance exercise performance. Extant research has focused on the valence and arousal dimensions of emotions, but not whether the motivational dimension (the extent to which the emotion engenders approach or avoidance behaviors) influences exercise performance. Two studies aimed to determine whether films and music chosen to induce approach- (i.e., anger), avoidance- (i.e., fear), and neutral-oriented emotions would successfully induce their intended emotional states (Study 1) and whether anger and fear emotion inductions would influence 2-mile time trial performance (Study 2). In Study 1, the films and music successfully induced their intended emotions. In Study 2, run time and perceived level of exertion did not differ between emotions across all participants or among faster running participants per a median split. However, among slower running participants, the anger induction increased the 2-mile running speed relative to the neutral induction. These findings suggest that emotions eliciting approach-related motivational states may improve exercise performance, particularly in slower runners.

**Keywords: exercise, motivation, approach, avoidance, emotion**

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## INTRODUCTION

Emotional states are thought to influence athletic performance. Multiple retrospective, cross-sectional studies suggest that precompetitive emotional states are associated with perceived athletic performance. For instance, emotional states perceived as under control were thought to facilitate swimming performance, whereas those perceived as out of control were thought to hinder performance (Hanton and Connaughton, 2002). Certain pleasant emotions such as interest and enjoyment and certain unpleasant emotions such as sadness, guilt, and self-hostility predicted perceived athletic performance (Cerin, 2003). Further, precompetitive unpleasant feelings of anger, confusion, depression, fatigue, and tension were associated with greater dysfunctional than optimal performance, whereas pleasant feelings of calmness, happiness, and vigor were associated with greater optimal than dysfunctional performance (Lane et al., 2010).

Within experimental work evaluating the influence of emotion on anaerobic exercise performance, relatively high-tempo "arousing" music during a 10-min warm-up increased peak anaerobic power (Eliakim et al., 2007; Jarraya et al., 2012). Similarly, "stimulating" music increased grip strength relative to "sedative" music (Pearce, 1981; Karageorghis et al., 1996). Other work has manipulated mood using imagery scripts and emotional pictures. Peak force produced during isometric leg extensions was greater following an imagery script intended to induce anger than those intended to induce happiness or a neutral emotional state (Woodman et al., 2009). Negative and positive pictures increased force strength on a handgrip exercise relative to neutral pictures (Schmidt et al., 2009).

Such results may translate to aerobic exercise performance as well, as "arousing" music intended to "emotionally charge up" participants enhanced 60-m dash performance among collegiate track and field sprinters (Hall and Erickson, 1995). Other research has found that music perceived as motivating benefitted self-reported running performance (Lane et al., 2011). Indeed, whether emotional states are perceived as functional or not functional may drive their impact on performance. According to the individual zones of optimal functioning (IZOF) model, emotions can be pleasant and unpleasant as well as functionally optimal or dysfunctional (Ruiz et al., 2017). For instance, experiencing anger and anxiety may alter performance in optimal and suboptimal ways between individuals and sports (Ruiz and Hanin, 2011). Thus, the extant literature generally suggests that arousing emotions, such as anxiety or anger, enhance exercise performance, but these effects differ across individuals. However, research has focused on relatively short-duration, often-anaerobic exercise performance, and the valence and arousal dimensions of emotions. To our knowledge, no study has examined the extent to which the motivational dimension of emotion influences aerobic exercise performance.

Emotional experience is thought to be organized by two distinct motivational systems: approach and avoidance (Carver, 2006). Anger and fear are two negative-valence, high-arousal emotions that occur in response to threat, but differ in the motivation they trigger to approach or avoid the threat (Newhagen, 1998). In other words, they are similar in valence and arousal, but differ in the motivational response they engender. Anger is appraised as a personal offense (Lazarus, 2000). It is approach-oriented in that it motivates an individual to attack the threat (Carver and Harmon-Jones, 2009). Fear is appraised as an impending danger (Lazarus, 2000) and is thus avoidance-oriented in that it motivates an individual to flee from threat (Lazarus, 2001; Lee and Lang, 2009).

Different motivational states are known to alter action dispositions and promote varied behavioral drives (Carver and Scheier, 1990; Davidson et al., 1990; Bradley, 2000). Traditionally, positive affect was associated with an approach-related drive, whereas negative affect was associated with an avoidance-related drive. However, there are some exceptions to this dissociation, namely, that within negatively valenced emotional states, fear can promote avoidance whereas anger can promote approach (Harmon-Jones and Allen, 1998; Harmon-Jones, 2003; Carver and Harmon-Jones, 2009). Inducing approach- versus avoidance-oriented motivational states can alter several aspects of cognitive and physical performance. For instance, inducing approach- or avoidance-related motivational states can improve cognitive control (Savine et al., 2010), and inducing anger can accelerate approach-related joint-specific and gross motor behaviors (Marsh et al., 2005; Mayan and Meiran, 2011). Regarding joint-specific behavior, researchers showed participants approach- or avoidance-inducing stimuli and found that approach states facilitated arm extension (reaching toward) and avoidance facilitated arm flexion (pulling away) (Marsh et al., 2005). Regarding gross motor behavior, researchers induced anxiety (avoidance) or anger (approach) and found that participants were faster to initiate a step forward in the approach versus avoidance and control conditions (Mayan and Meiran, 2011). Some believe that the priming of approach-oriented behavior under conditions of anger is due to a disruption of a broader need to satisfy goals and an increased drive to behaviorally "push forward" and pursue those goals (Frijda, 1988). However, it is unknown whether any such effects of motivational states are robust enough to alter whole-body aerobic exercise performance.

The present studies fulfill two primary objectives in relation to this extant research. First, we seek to extend research examining motivational state influences on behavior, better isolating the influence of motivational states (in addition to arousal and valence effects) on behaviors increasingly reflective of real-world actions (i.e., athletic performance). Second, we seek to extend research showing the influence of motivational states on single-joint and step onset-related behaviors by examining whole-body aerobic exercise. To accomplish these objectives, we conducted two studies. The first aimed to determine whether films and music chosen to induce anger, fear, and neutral emotions would successfully induce those emotions (Study 1), and the second aimed to determine whether anger- and fear-associated motivational state inductions would influence aerobic exercise (in the form of 2-mile time trial performance) relative to a neutral motivational state induction (Study 2).

# STUDY 1

## Methods

### Participants

Thirty-four individuals (20 women; age 18–50 years) participated for monetary compensation of $20 USD per hour (see **Table 1**). Informed consent was obtained from all individual participants included in the study, and both the Tufts University Institutional Review Board and the Army Human Research Protections Office approved all procedures.

### Research Design

Study 1 used a repeated measures design, with motivational state induction (approach, avoidance, neutral) as the within-participants factor. Sample size estimation was based on effect sizes from Lane et al. (2010) who found that emotional states were associated with optimal and dysfunctional performance ($\eta_p^2$ = 0.39). Using G*Power (Faul et al., 2007) the necessary sample size was estimated to be 21 with an alpha level of $p = 0.05$, a power of 0.95, using repeated measures analysis of variance (ANOVA) with two degrees of freedom (Lane et al., 2010).

**TABLE 1** | Study 1 sample characteristics ($n$ = 34).

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Age | 25.5 | 7.3 | 18 | 50 |
| BMI | 25.0 | 6.0 | 19.4 | 41.2 |
| Godin Leisure Time Questionnaire | 50.8 | 28.7 | 0 | 107 |
| BAS Drive | 8.5 | 2.5 | 5 | 15 |
| BAS Fun Seeking | 8.2 | 2.3 | 4 | 14 |
| BAS Reward Responsiveness | 7.3 | 2.6 | 5 | 15 |
| BIS | 13.4 | 3.8 | 8 | 21 |

*BMI, body mass index; BAS, Behavioral Activation System; BIS, Behavioral Inhibition System.*

## Measures

The Godin Leisure Time Exercise Questionnaire and Behavioral Approach System/Behavioral Avoidance System (BAS/BIS) were administered at the start of the study to capture sample characteristics. The Discrete Emotions Questionnaire (DEQ) was administered at multiple time points during each of the three experimental sessions.

### *Godin leisure time questionnaire*

The Godin Leisure Time Exercise Questionnaire quantified participants' activity level and asked participants the number of times they engaged in strenuous, moderate, and light exercise for at least 15 min over an average week (Godin and Shephard, 1985). Weekly frequencies of strenuous, moderate, and light activities are then multiplied by nine, five, and three, respectively, to calculate a weekly leisure activity score. Individuals who score at least 24 are considered active, and those who score less than 14 are considered inactive (Godin, 2011). The Godin Leisure Time Questionnaire has been shown to be valid in classifying individuals as active and insufficiently active (Amireault and Godin, 2015).

### *Behavioral approach system/behavioral avoidance system (BAS/BIS) scales*

The BAS/BIS scales evaluated individual differences in approach and avoidance motivation systems (Carver and White, 1994). The BIS/BAS scales consist of a single Inhibition scale and Approach subscales of Reward Responsiveness, Drive, and Fun Seeking. Participants are asked to respond to 24 items by indicating on a four-point scale how true each statement is from them (e.g., "I crave excitement and new sensations" and "I worry about making mistakes"). The BIS/BAS show adequate internal consistency reliability ($\alpha$ = 0.66–0.76) (Carver and White, 1994) and test–retest reliability (ICC = 0.41–0.42) (Schneider et al., 2016).

### *The discrete emotions questionnaire (DEQ)*

The anger and fear subscales of the DEQ measured participants' self-reported feelings of anger and fear. Participants rated the extent to which they experienced emotions such as "anger," "rage," and "mad" (anger subscale) and "scared," "panic," and "fear" (fear subscale) on a scale ranging from "Not at all" (1) to "An extreme amount" (7). These subscales show adequate internal consistency reliability ($\alpha \geq 0.92$) and sensitivity to detect changes in discrete emotions (Harmon-Jones et al., 2016).

### *Motivational state induction*

Approach and avoidance motivational states were operationalized by experimentally inducing feelings of anger and fear, based on evidence that anger and fear are both negative-valence, high-arousal emotions that occur in response to threat, but differ in the motivation they generate to approach (anger) or avoid (fear) the threat (Newhagen, 1998). To do so, participants viewed a series of films previously validated to engender neutral, fearful, or angry feelings (Betz et al., 2015). Four film clips (11 min, 17 s) used to induce anger included news stories of sexual and verbal harassment and gang violence, and a movie featuring verbal child abuse. Three film clips (11 min, 47 s) used to induce fear included individuals being chased by unseen threats and unexpected appearances of ghost-like individuals. Three film clips (9 min, 35 s) used to induce a neutral emotional state included a lesson on descriptive statistics, office discussions, and a bowling competition. To extend the motivational state induction, participants listened to music that was also validated to evoke neutral, fearful, or angry feelings (Ford et al., 2010). The music consisted of 5-min instrumental pieces played on repeat.

## Procedure

First, informed consent was obtained from all individual participants. Participants then completed the Godin Leisure Time Questionnaire and the BAS/BIS scales. Participants then completed a baseline DEQ. Participants watched the neutral-, anger-, or fear-inducing films. They then completed a DEQ immediately following the films. Next, the neutral-, anger-, or fear-inducing music was started, which continued for the next 30 min. During this time, participants completed the DEQ every 5 min. The three test sessions were spaced at least 1 day apart and were identical except for the motivational state induction. Following the third test session, participants were fully debriefed and compensated for their participation.

## Statistical Methods

The DEQ was analyzed using a repeated measures ANOVA with motivational state induction (Neutral, Anger, Fear), and Time (Pre-Induction, Minutes 0, 5, 10, 15, 20, 25, 30 Post-Induction) as within-participant factors.

An effect was deemed statistically significant if the likelihood of its occurrence by chance was $p < 0.05$. When sphericity was violated, Greenhouse–Geisser corrected $p$-values were used. When an ANOVA yielded a significant main effect, *post hoc* tests using the Bonferroni correction were conducted. Effect sizes are reported as $\eta^2$ for ANOVAs and Cohen's $dz$ for $t$-tests (Lakens, 2013). All statistical analyses described above were performed using SPSS 21.0.

# Results

Analysis of self-reported anger showed main effects of motivational state induction, $F(2,66) = 17.671$, $p < 0.001$ ($\eta^2 = 0.261$), and time, $F(7,231) = 7.840$, $p < 0.001$ ($\eta^2 = 0.057$), which were qualified by a motivational state induction by time interaction, $F(14,462) = 8.293$, $p < 0.001$ ($\eta^2 = 0.111$); see **Table 2**. Follow-up tests showed that self-reported anger was greater during the anger than neutral or fear induction immediately

**TABLE 2 |** Study 1 self-reported anger and fear before, during, and after anger, fear, and neutral motivational state inductions ($n$ = 34).

| | | Self-reported anger | | | | Self-reported fear | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Mean** | **SEM** | **Min** | **Max** | **Mean** | **SEM** | **Min** | **Max** |
| Anger induction film | Pre-induction | 1.16 | 0.07 | 1.00 | 2.75 | 1.13 | 0.05 | 1.00 | 2.00 |
| | 0 min Post-induction | 3.49 | 0.28 | 1.00 | 7.00 | 1.88 | 0.19 | 1.00 | 5.00 |
| | 5 min Post-induction | 2.03 | 0.22 | 1.00 | 5.33 | 1.55 | 0.18 | 1.00 | 5.75 |
| | 10 min Post-induction | 2.08 | 0.28 | 1.00 | 7.00 | 1.51 | 0.19 | 1.00 | 5.75 |
| | 15 min Post-induction | 2.18 | 0.32 | 1.00 | 6.67 | 1.61 | 0.21 | 1.00 | 6.00 |
| | 20 min Post-induction | 2.22 | 0.32 | 1.00 | 7.00 | 1.60 | 0.22 | 1.00 | 6.00 |
| | 25 min Post-induction | 2.25 | 0.33 | 1.00 | 7.00 | 1.63 | 0.20 | 1.00 | 6.25 |
| | 30 min Post-induction | 2.27 | 0.33 | 1.00 | 7.00 | 1.68 | 0.24 | 1.00 | 6.00 |
| Fear induction film | Pre-induction | 1.28 | 0.14 | 1.00 | 5.25 | 1.17 | 0.10 | 1.00 | 3.75 |
| | 0 min Post-induction | 1.39 | 0.11 | 1.00 | 3.33 | 3.25 | 0.32 | 1.00 | 7.00 |
| | 5 min Post-induction | 1.30 | 0.15 | 1.00 | 6.00 | 2.04 | 0.22 | 1.00 | 5.75 |
| | 10 min Post-induction | 1.53 | 0.20 | 1.00 | 6.67 | 1.85 | 0.20 | 1.00 | 5.00 |
| | 15 min Post-induction | 1.38 | 0.15 | 1.00 | 5.67 | 1.65 | 0.19 | 1.00 | 5.75 |
| | 20 min Post-induction | 1.35 | 0.14 | 1.00 | 5.00 | 1.43 | 0.16 | 1.00 | 4.75 |
| | 25 min Post-induction | 1.47 | 0.19 | 1.00 | 6.33 | 1.43 | 0.20 | 1.00 | 6.75 |
| | 30 min Post-induction | 1.70 | 0.25 | 1.00 | 7.00 | 1.41 | 0.17 | 1.00 | 4.75 |
| Neutral induction film | pre-induction | 1.29 | 0.12 | 1.00 | 4.67 | 1.25 | 0.10 | 1.00 | 3.25 |
| | 0 min Post-induction | 1.15 | 0.10 | 1.00 | 4.00 | 1.07 | 0.03 | 1.00 | 1.75 |
| | 5 min Post-induction | 1.10 | 0.05 | 1.00 | 2.33 | 1.04 | 0.03 | 1.00 | 1.75 |
| | 10 min Post-induction | 1.10 | 0.06 | 1.00 | 2.67 | 1.07 | 0.04 | 1.00 | 1.75 |
| | 15 min Post-induction | 1.14 | 0.07 | 1.00 | 2.67 | 1.07 | 0.03 | 1.00 | 1.75 |
| | 20 min Post-induction | 1.23 | 0.11 | 1.00 | 4.33 | 1.05 | 0.03 | 1.00 | 2.00 |
| | 25 min Post-induction | 1.16 | 0.07 | 1.00 | 2.75 | 1.10 | 0.04 | 1.00 | 2.00 |
| | 30 min Post-induction | 1.27 | 0.10 | 1.00 | 3.25 | 1.07 | 0.03 | 1.00 | 1.75 |

*SEM, standard error of the mean.*

through 25 min following the films ($p$-values $<$ 0.01). Thirty minutes following the films, self-reported anger was greater during the anger than neutral induction ($p$ = 0.003), but did not differ between the anger and fear induction ($p$ = 0.081). Self-reported anger did not differ across motivational state inductions before inductions ($p$ = 0.61).

Analysis of self-reported fear showed main effects of motivational state induction, $F(2,66)$ = 13.534, $p$ $<$ 0.001 ($\eta^2$ = 0.113), and time, $F(7,231)$ = 14.874, $p$ $<$ 0.001 ($\eta^2$ = 0.080), which were qualified by a motivational state induction by time interaction, $F(14,462)$ = 14.839, $p$ $<$ 0.001 ($\eta^2$ = 0.109). Follow-up tests showed that self-reported fear was greater during the fear than neutral or anger induction immediately through 10 min following the films ($p$-values $<$ 0.001). Self-reported fear was greater during the fear than neutral condition 15, 20, and 30 min following the films ($p$-values $<$ 0.05), but did not differ between fear and anger at these time points ($p$-values $>$ 0.15).

## Discussion

As expected, the anger- and fear-inducing films and music increased self-reported anger and fear, respectively. Specifically, anger-inducing films and music resulted in higher self-reported anger than fear for at least 25 min following viewing the films. Similarly, fear-inducing films and music resulted in higher self-reported fear than anger for at least 10 min following viewing the films. Both inductions increased their intended emotions relative to neutral for the entire 30 min. Such findings suggest that the chosen films and music will similarly induce anger and fear states throughout the 2-mile time trial in Study 2, given that the median pace in 5-km races is 9:16 min per mile in men and 11:15 min per mile in women (Douglas and Fuehrer, 2014).

# STUDY 2

## Methods

### Participants

Thirty-four individuals (19 women; age 18–35 years) participated for monetary compensation of US$150 (see **Table 3**). All participants exercised for at least 30 min of moderate-intensity cardiorespiratory exercise 5 or more days per week, or at least 20 min of vigorous-intensity cardiorespiratory exercise for at least 3 days per week (Garber et al., 2011), and ran at least 2 consecutive miles in 2 weeks prior to their participation. Participants also had healthy vision and hearing, were not pregnant or nursing, and did not have any contraindications to exercise such as orthopedic injuries, heart or lung problems, or asthma. Informed consent was obtained from all individual participants included in the study, and both the United States Army Research, Development, and Engineering

**TABLE 3 |** Study 2 sample characteristics ($n$ = 34).

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Age | 24.9 | 4.8 | 18 | 34 |
| BMI | 21.5 | 2.3 | 18.0 | 29.3 |
| Cardiorespiratory exercise (minutes/week) | 284.8 | 192.4 | 60 | 1086 |
| Longest weekly run (miles) | 6.5 | 5.6 | 2 | 33 |
| Godin Leisure Time Questionnaire | 68.8 | 17.4 | 38 | 101 |
| BAS Drive | 8.1 | 2.3 | 4 | 14 |
| BAS Fun Seeking | 7.3 | 2.1 | 4 | 12 |
| BAS Reward Responsiveness | 7.3 | 1.9 | 5 | 12 |
| BIS | 14.4 | 3.2 | 8 | 20 |

*BMI, body mass index; BAS, Behavioral Activation System; BIS, Behavioral Inhibition System.*

Command and the Tufts University Institutional Review Board approved all procedures.

## Research Design

Study 2 used a repeated measures design, with motivational state induction (approach, avoidance, neutral) and Time (Pre-Induction, Post-Induction, Mile 1, Post-Cool-down, Post-Recovery) as within-participant factors. Sample size estimation was identical to Experiment 1, with the necessary sample size of 21 (Lane et al., 2010).

## Measures

As in Study 1, the Godin Leisure Time Exercise Questionnaire and BAS/BIS were administered at the start of the study to capture sample characteristics. The DEQ and Borg Rated Perceived Exertion (RPE) Scale were before, during, and after exercise to measure endurance exercise experience. Approach and avoidance motivational states were experimentally induced using the same films and music as Study 1.

### *Borg rated perceived exertion (RPE) scale*

This commonly used one-item self-report scale measures perceived physical exertion (Borg, 1982). Participants were told, "Choose the number that best describes your level of exertion," on a scale ranging from "no exertion at all" (6) to "maximal exertion" (20).

### *Two-mile time trial*

Participants first warmed up for 5 min by walking at 2.5 miles per hour (MPH). After 5 min, they ran for 2 miles at a self-selected pace intended to mimic race conditions. After 2 miles, they cooled down by walking at 2.5 MPH for 5 min and then sat quietly for a 15-minute recovery period. The 2-mile time trial was chosen as it is a common test of physical fitness (e.g., it is a component of the Army Physical Fitness test; Knapik and East, 2014) and is highly correlated with maximal oxygen consumption, a test of aerobic fitness capacity (Mello et al., 1987). Participants were given the following instructions before beginning the time trial:

> "You will now complete a 2-mile time trial. You will run for 2 miles. Your goal is to complete the 2 miles as quickly as possible. You should also run within a pace that you feel you can safely maintain, that is, we do not want you to run at a pace that may cause you to trip or in any way injure yourself. Your cumulative distance will be displayed on the treadmill, but your pace and time will be hidden. You will be asked to complete two questionnaires while running, when you finish the first mile, which will ask about your level of physical exertion and emotions. You will answer these questions using the keypad on the treadmill. Do you have any questions?"

## Procedure

First, informed consent was obtained from all individual participants. Participants were then screened for eligibility. If selected to participate, they completed the Godin Leisure Time Questionnaire and the BAS/BIS scales. Participants then donned a heart rate monitor and completed a baseline DEQ. Participants watched the neutral-, anger-, or fear-inducing films and completed the DEQ and RPE. Next, the neutral-, anger-, or fear-inducing music was started, and participants warmed up at a slow speed (2.5 MPH) for 5 min. Participants completed a 2-mile time trial, during which they completed the DEQ and RPE at mile 1. Participants then cooled down at 2.5 MPH for 5 min and completed the DEQ and RPE. The music was stopped, and participants sat quietly for a 15-min recovery period, during which time they had no access to distractions such as technology or reading material. Following recovery, participants completed a final DEQ and RPE, and watched a short positive film intended to reverse any negative emotions induced by the films and music (see **Figure 1** for schematic representation of the study schedule). Throughout the test sessions, heart rate data were collected using Polar telemetry (Polar RS800CX). The three test sessions were spaced at least 1 week apart and were identical except for the motivational state induction. Following the third test session, participants were fully debriefed and compensated for their participation.

To reduce diurnal variation in cognitive and physical performance, test sessions were scheduled at the approximate same time of day within participants (±1 h). To reduce the influence of hydration status on physical performance, participants were asked to consume ½ L of water the night before a test session, and ½ L of water the morning of a test session. Participants were also required to consume at least one meal prior to a morning test session (i.e., breakfast) and at least two meals prior to an afternoon test session (i.e., breakfast, lunch). They were asked to abstain from alcohol intake for 24 h prior to the experiment.

## Statistical Methods

Discrete Emotions Questionnaire, RPE, heart rate, and 2-mile run time were analyzed using repeated measures ANOVAs with motivational state induction (Neutral, Anger, Fear) and, where appropriate, Time (Pre-Induction, Post-Induction, Mile 1, Post-Cool-Down, Post-Recovery) as within-participant factors.

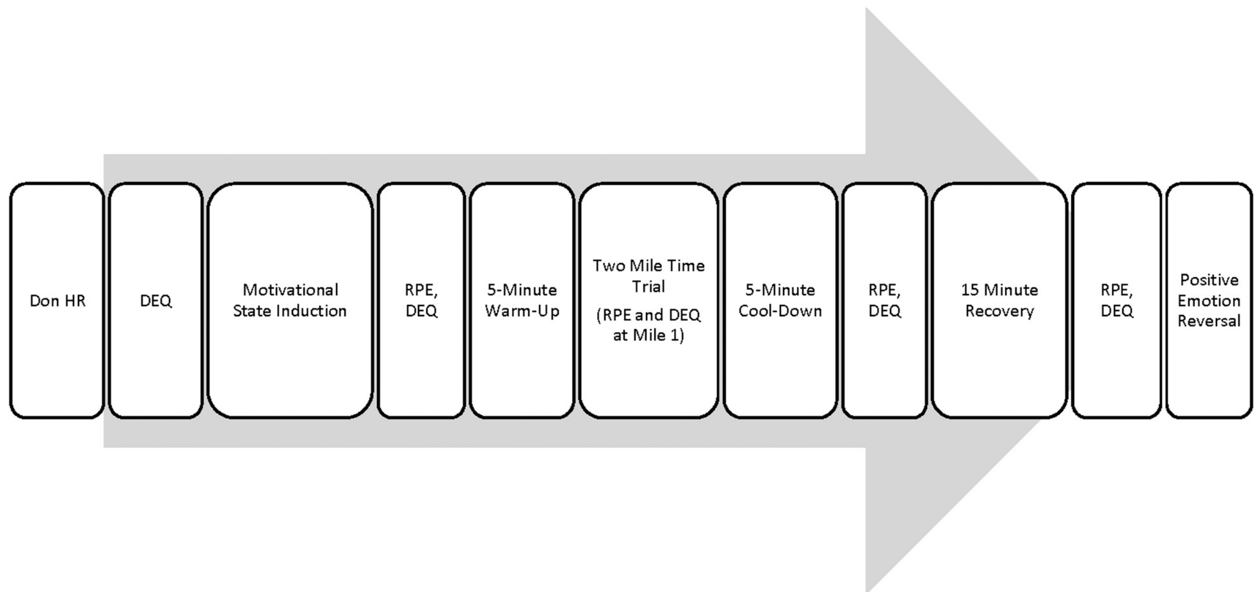


**FIGURE 1 |** Schematic of Study 2 schedule.

## Results

### Two-Mile Run Time

Across all participants, the 2-mile run time did not differ across motivational state induction ($p$ = 0.331). In order to determine whether motivation states differentially influenced faster versus slower runners (Baldari et al., 2010), the 2-mile run times during the neutral condition were divided into fast and slow using the median splits method (the median cutoff point was 17:43 min), resulting in 17 participants (seven women, 10 men) with fast run times and 17 participants (12 women, five men) with slow run times. Among the faster participants, the 2-mile run time did not differ across motivational state induction ($p$ = 0.448). Among slower participants, the anger induction reduced the 2-mile run time relative to the neutral induction, but did not differ from the fear induction, $F(2,32) = 3.786$, $p = 0.033$ ($\eta^2 = 0.191$); see **Figure 2**.

### RPE

Rated Perceived Exertion was greater at mile 1 and upon completion of the cool-down than before the warm-up, but did not differ between before the warm-up and after the 15-min recovery period, $F(3,99) = 104.130$, $p < 0.001$ ($\eta^2 = 0.661$). RPE did not differ as a function of motivation state induction or motivational state induction by time ($p$'s > 0.33). RPE did not differ between the faster and slower participants (all $p$-values > 0.38).

### DEQ

Analysis of self-reported anger showed main effects of motivational state induction, $F(2,66) = 30.664$, $p < 0.001$ ($\eta^2 = 0.135$), and time, $F(4,132) = 24.897$, $p < 0.001$ ($\eta^2 = 0.105$), which were qualified by a motivational state induction by time interaction, $F(8,264) = 27.920$, $p < 0.001$ ($\eta^2 = 0.218$); see **Table 4**. Follow-up tests showed that self-reported anger was greater during the anger than neutral or fear induction immediately following the films, $F(2,66) = 79.391$, $p < 0.001$ ($\eta^2 = 0.706$), and at mile 1, $F(2,66) = 8.035$, $p = 0.001$ ($\eta^2 = 0.040$), and self-reported anger was greater during the anger than fear induction upon completion of the cool-down, $F(2,66) = 3.735$, $p = 0.029$ ($\eta^2 = 0.030$). Self-reported anger did not differ across motivational state inductions before inductions or after the 15-min recovery ($p$'s > 0.29).

Analysis of self-reported fear showed main effects of motivational state induction, $F(2,66) = 15.415$, $p < 0.001$ ($\eta^2 = 0.072$), and time, $F(4,132) = 34.274$, $p < 0.001$ ($\eta^2 = 0.166$), which were qualified by a motivational state induction by time interaction, $F(8,264) = 22.025$, $p < 0.001$ ($\eta^2 = 0.179$). Follow-up tests showed that self-reported fear was greater during the fear than neutral or anger induction immediately following the films, $F(2,66) = 32.325$, $p < 0.001$ ($\eta^2 = 0.780$), but not other time points ($p$'s > 0.06).

### HR

HR was missing for two participants due to the dropped signal by the HR monitor. HR was lower during the motivational state induction than all subsequent time points, and higher during the run than all other time points, $F(4,124) = 885.496$, $p < 0.001$ ($\eta^2 = 0.919$). HR did not differ as a function of motivation state induction or motivational state induction by time ($p$'s > 0.11).

## Discussion

Study 2 examined whether experimentally induced approach- and avoidance-oriented motivational states would influence running performance on a 2-mile time trial. All participants were regular exercisers, who scored at least 38 on the Godin Leisure Time Questionnaire, where a score of 24 is considered "active" (Amireault and Godin, 2015). They watched films validated in Study 1 to induce fear, anger, and neutral emotions, and then ran

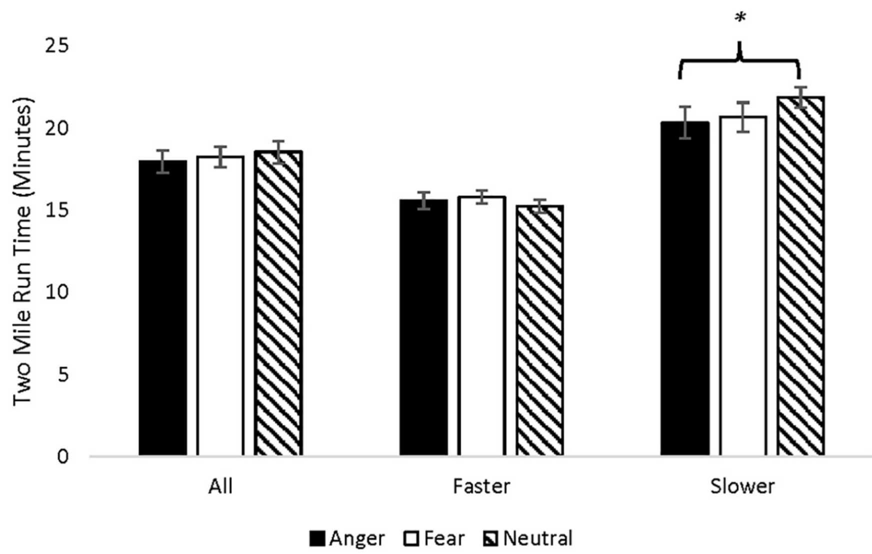


**FIGURE 2 |** Two mile run time means (SEM) for each motivational state induction and running speed.

**TABLE 4 |** Study 2 self-reported anger and fear (*n* = 34).

| | | Self-reported anger | | | | Self-reported fear | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Mean** | **SEM** | **Min** | **Max** | **Mean** | **SEM** | **Min** | **Max** |
| Anger induction | Pre-induction | 1.08 | 0.04 | 1.00 | 2.00 | 1.02 | 0.01 | 1.00 | 1.25 |
| | Post-induction | 2.85 | 0.18 | 1.00 | 4.75 | 1.48 | 0.13 | 1.00 | 4.00 |
| | Mile 1 | 1.65 | 0.13 | 1.00 | 3.75 | 1.35 | 0.14 | 1.00 | 4.50 |
| | Post-cool-down | 1.52 | 0.17 | 1.00 | 4.75 | 1.33 | 0.13 | 1.00 | 4.00 |
| | Post-recovery | 1.15 | 0.08 | 1.00 | 3.50 | 1.17 | 0.12 | 1.00 | 4.75 |
| Fear induction | Pre-induction | 1.17 | 0.10 | 1.00 | 4.00 | 1.08 | 0.04 | 1.00 | 2.25 |
| | Post-induction | 1.11 | 0.07 | 1.00 | 3.00 | 3.16 | 0.28 | 1.00 | 6.00 |
| | Mile 1 | 1.21 | 0.07 | 1.00 | 2.50 | 1.38 | 0.12 | 1.00 | 3.50 |
| | Post-cool-down | 1.13 | 0.06 | 1.00 | 2.25 | 1.40 | 0.16 | 1.00 | 4.75 |
| | Post-recovery | 1.04 | 0.02 | 1.00 | 1.75 | 1.10 | 0.07 | 1.00 | 3.25 |
| Neutral induction | Pre-induction | 1.05 | 0.04 | 1.00 | 2.00 | 1.07 | 0.04 | 1.00 | 2.00 |
| | Post-induction | 1.08 | 0.04 | 1.00 | 2.00 | 1.20 | 0.11 | 1.00 | 3.75 |
| | Mile 1 | 1.26 | 0.08 | 1.00 | 2.50 | 1.22 | 0.07 | 1.00 | 2.50 |
| | Post-cool-down | 1.20 | 0.08 | 1.00 | 2.75 | 1.08 | 0.05 | 1.00 | 2.50 |
| | Post-recovery | 1.15 | 0.07 | 1.00 | 2.75 | 1.03 | 0.03 | 1.00 | 2.00 |

*SEM, standard error of the mean.*

2 miles as fast as possible while listening to music validated to induce the same emotions.

Results revealed that anger enhanced 2-mile time trial performance among participants whose 2-mile run times fell above (i.e., were slower than) the median during the neutral condition. Anger or fear did not influence the 2-mile time trial performance among participants whose times fell below (i.e., were faster than) the median or the sample as a whole. The results support previous research that music intended to increase emotional arousal enhanced aerobic and anaerobic exercise performance (Hall and Erickson, 1995; Karageorghis et al., 1996; Eliakim et al., 2007; Jarraya et al., 2012). The results also support the findings that less-active individuals experienced longer times to exhaustion when they listened to fast-tempo music than no music, whereas more-active individuals experienced no such effect of music (Baldari et al., 2010). The results extend this research by suggesting that the arousal component of emotions cannot entirely account for the results, as both our anger and fear inductions were characterized as high arousal, negative valence emotions. Our findings suggest that motivational states elicited may differentiate emotional states regarding their effects on athletic performance in certain individuals, but that there is no clear effect of the two motivational state components on 2-mile run times. This finding complements the work done with single-joint and gross motor behavior, and extends it to the domain of whole-body aerobic exercise, a behavior that characterizes many people's daily lives. The results may also support research showing that viewing a competitive sprint cycling task, the Wingate test, as a challenge enhanced performance relative to viewing it as a threat (Wood et al., 2018). However, the findings should be interpreted with caution, as we did not find effects of anger across the sample as a whole, and did not include a measure of physical fitness such as maximum oxygen update ($VO_{2max}$) to differentiate participants on the basis of aerobic capacity.

Rated perceived exertion did not differ between motivational state conditions or between faster and slower participants. Previous research has suggested that certain emotions, such as viewing positive relative to neutral pictures, reduced perceived exertion during exercise (Schmidt et al., 2009). Research comparing listening to music to no music has also found reduced perceived exertion across a range of music genres and exercise intensities (Szmedra and Bacharach, 1998; Potteiger et al., 2000; Yamashita et al., 2006). Thus, it is possible that listening to any music, regardless of the emotional or motivational state it engenders, benefits exertion responses to exercise.

Self-reported emotion showed that participants felt more anger than fear throughout the run and cool-down during the anger induction. However, their feelings of fear relative to anger dissipated by the first mile of the run. Given that the fear induction persisted for at least 10 min relative to anger, and at least 30 min to neutral in Study 1, it is possible that the 2-mile time trial itself mitigated emotional responses to fear. Although, to our knowledge, no research has examined the effect of exercise on feelings of fear, the findings support research indicating that exercise reduces state anxiety (Petruzzello et al., 1991; Ensari et al., 2015). Research employing the Profile of Mood States has also found reductions in the anger-hostility subscale following exercise (Berger and Motl, 2000). The present research was not designed to test the influence of exercise on fear and anger states, but may provide preliminary evidence that exercise ameliorates emotions that elicit avoidance-oriented motivational states such as fear.

The emotion inductions elicited relatively low levels of anger and fear. Indeed, on a scale ranging from 1 ("Not at all") to 7 ("An extreme amount"), participants' self-reported anger averaged 3.5 immediately after watching the anger-inducing films, and their self-reported fear averaged 3.25 immediately after the fear-inducing films. Laboratory or real life events, such as embarking on a run frustrated over racial inequities or fearful for a family members' health, that elicit these emotional-triggering motivational states to a greater degree may have great effects on athletic performance.

Together the findings suggest that approach-oriented motivational states such as those elicited by anger may improve running performance, but that the effects are thus far limited to certain individuals such as slower running, and thus unclear. The results have implications for the nature of motivational preparation prior to athletic events that will benefit the performance the most, as well as how emotion regulation strategies could be employed to switch motivational states to ones that are most beneficial to athletic performance.

## DATA AVAILABILITY STATEMENT

The datasets for this article are not publicly available because the funding agency does not permit public release of data products. Requests to access the datasets should be directed to GE, grace.e.giles4.civ@mail.mil.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the United States Army Research, Development, and Engineering Command and the Tufts University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

GG, EA, and TB contributed to the study concept. GG, CH, and GE completed the data preparation. GG wrote the first draft of the manuscript. All authors contributed to the data analysis, manuscript revision, and read and approved the submitted version.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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# Young Adults' Short-Term Trajectories of Moderate Physical Activity: Relations With Self-Evaluation Processes

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Young adults face numerous barriers that can undermine their engagement in healthy behaviors. For example, young adults on average experience disproportionally large declines in physical activity (PA) participation compared to other demographic groups. Self-evaluation processes may help explain these declines. This study investigated young adults' weekly trajectories of moderate physical activity, exploring self-evaluation processes, including self-efficacy and shame as time-varying covariates. A total of 71 young adults (*M*age = 21.25, *SD* = 1.18; 55% male) reported moderate physical activity, exercise self-efficacy, and anticipated shame toward exercise once a week for 5 weeks. Latent growth curve models showed that a linear slope fit these data better than alternative models. Parameters of the linear model revealed that these young adults reported engaging in 40 min of moderate PA approximately 3 days per week. However, there were physical activity differences in initial levels and rates of change. Exercise self-efficacy consistently predicted physical activity in a positive direction and with a small-to-medium magnitude. Anticipated shame was an inconsistent predictor of physical activity, showing a negative direction and small magnitude at time one and on average across the 5 weeks. These findings highlight considerable variability in young adults' short-term trajectories of physical activity and underscore both positive and negative processes of exercise related self-evaluations. Future physical activity interventions targeting young adults should incorporate strategies that enhance self-efficacy (e.g., mastery experiences) and reduce feelings of shame (e.g., attribution training).

**Keywords: emotions, exercise, motivation, self-efficacy, shame**

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## INTRODUCTION

Regular participation in physical activity (PA) is a lifestyle habit that enhances physiological and psychosocial wellbeing across all segments of the population (United States Department of Health and Human Services, 2018). Regular PA also reduces risk for developing non-communicable diseases that can reduce quality of life and cause mortality (Piercy et al., 2018). In fact, evidence underscores increasing rates of preventable risk factors such as obesity and cardiovascular disease in younger populations (Wittekind et al., 2018). Young adults are one segment of the population who, on average, experience disproportionally large declines in regular PA during the transition from adolescence (Zick et al., 2007; Kwan et al., 2012). Among different segments of the young adult population, those who enroll in post-secondary education appear to be at greatest risk for experiencing declines in PA (Bray and Born, 2004). According to American College Health Association (2020), less than half of college and university students in the United States meet PA recommended guidelines related to aerobic activity and less than 40% related to muscular strength and endurance. In fact, evidence suggests that college and university students throughout the world often fail to meet PA guidelines (Haase et al., 2004).

PA participation is a complex endeavor; therefore, explaining declines in young adults' PA is a difficult process. Combinations of environmental and biopsychosocial factors potentially cause variations in both short-term and long-term PA patterns. In general, many young adults who attend college or university experience major life changes such as moving away from home for the first time, having greater independence in day-to-day decision making, and experiencing changes in peer groups that for many appear to undermine health (Pullman et al., 2009; Deforche et al., 2015). Other factors such as work and/or school demands, sickness, competence beliefs, weather, access to facilities, and social support can facilitate or disrupt young adults' PA on a daily, weekly, monthly, and/or yearly interval.

Although evidence suggests that many college and university students fail to meet PA guidelines (Haase et al., 2004), there remain gaps to understanding how young adults' engagement in PA changes over time. For example, cross-sectional studies provide no information on changes in young adults' PA behavior (e.g., Drenowatz et al., 2015). Intervention studies provide important information on how young adults' PA behavior changes under controlled conditions but rarely explores intra-individual changes (e.g., Fiebert et al., 2004). Furthermore, these studies often assume homogeneity in PA behavior within the sample at baseline. There is a clear need for investigating within person trajectories of young adults' PA, including naturally occurring factors that may help explain individual patterns (Lemoyne et al., 2016). Currently there is conflicting evidence on the nature of change in young adults' PA with research demonstrating both increases (Lemoyne et al., 2016) and decreases (Lounassalo et al., 2019) over time. In this study, we investigate young adults' weekly PA trajectories, examining whether self-evaluation processes help explain individual differences in these trajectories. Specifically, we explore two self-evaluation processes (Tracy and Robins, 2004; Baldwin et al., 2006): exercise self-efficacy and anticipated shame. In the paragraphs below, we define exercise self-efficacy and anticipated shame within the context of self-evaluation; describe how self-evaluation links to health behaviors such as PA; and outline the purpose and specific hypotheses of the study.

## Self-Evaluation and Physical Activity

People strive to maintain a positive sense of self, seeking out opportunities that facilitate positive and avoiding situations that produce negative self-evaluations (Baumeister, 1999; Marsh, 1990). Theorists suggest self-evaluation processes such as self-efficacy and shame influence how individuals interpret, act, and react within their environment (Bandura, 2004; Baldwin et al., 2006). Self-evaluation provides a common link between self-efficacy and shame. Bandura (1997) defines self-efficacy as one's beliefs about capabilities to engage in behaviors that lead to specific performance achievements. Individuals rely on self-evaluation (e.g., "do I have the capability to run a mile in 8:00 min?") when making judgments about their self-efficacy (Bandura, 2004). Shame also requires self-evaluation, representing a self-conscious, negative emotion whereby individuals believe they have or will fail to meet an internal and/or external standard, resulting in self-degradation (Tracy and Robins, 2004). Self-efficacy is central to health behaviors because people have little incentive to take action and persist unless they believe in their abilities to produce desired outcomes (Bandura, 2004). Likewise, feelings of shame can reduce health behaviors through ambivalence, aversion, and withdraw (Danielson et al., 2016). Together, self-efficacy (i.e., can I do it?) and shame (i.e., how will I feel if I fail to do it?) reflect common cognitive and emotional self-evaluation processes that direct behavioral engagement and previous research establishes connections between self-evaluation and various health behaviors, including PA (Castonguay et al., 2017).

Self-efficacy is arguably the single strongest self-evaluation determinant of PA adoption, adherence, and maintenance (McAuley and Blissmer, 2000; Wallace et al., 2000; Amireault et al., 2012). This evidence is robust across different demographics, time intervals, parameters of PA, study designs, and study contexts. For example, PA studies demonstrate that self-efficacy consistently enhances future PA in youth (Dishman et al., 2004), young adults (Parschau et al., 2012; Farren et al., 2017), adults (Dallow and Anderson, 2003), and older adults (Clark, 1996). However, Anderson-Bill et al. (2011) revealed that exercise self-efficacy tends to decline with age. Research also demonstrates that self-efficacy predicts changes in both short-term (Courneya and McAuley, 1994) and long-term (Amireault et al., 2012) PA. Courneya and McAuley (1994) also reported self-efficacy as a predictor of both frequency and intensity of PA in young adults.

Both observational (e.g., Farren et al., 2017) and intervention studies (e.g., McAuley et al., 2012) consistently highlight the importance of self-efficacy in relation to PA. For example, in a review of PA interventions ($n$ = 20), Williams and French (2011) reported that the correlation between changes in self-efficacy and changes in PA was robust ($r$ = 0.69). Self-efficacy is also a crucial determinant of PA maintenance. In a meta-analysis study of PA intervention studies conducted by Amireault et al. (2012), participants with higher levels of self-efficacy at baseline were more likely to be physically active and less likely to relapse 6 or more months post intervention. Finally, using self-efficacy as a tool for promoting PA can be across a variety of contexts, including school (Dishman et al., 2004), faith (Anderson-Bill et al., 2011), health (Maddison et al., 2014), and leisure (Farren et al., 2017) settings.

Self-efficacy is also theorized to affect other psychosocial factors of health behaviors such as goal setting and intentions

(Bandura, 2004; Buchan et al., 2012) as well as affective responses (Magnan et al., 2013). Collectively, these robust links between self-efficacy and PA make it a central factor in the investigation of health behaviors. However, a majority of these studies has focused on the ability of self-efficacy to explain inter-individual differences in PA (Buchan et al., 2012). In other words, most studies examine how self-efficacy relates to differences or the average magnitude of change between groups of people. Few studies explore how self-efficacy relates to intra-individual changes in PA. This is a different research question that can potentially help uncover how well self-efficacy explains PA changes and its heterogeneity within individuals. This type of approach provides a dynamic perspective of understanding behavior change processes (Reuter et al., 2010).

Another appealing characteristic of focusing on self-efficacy to understand health behavior such as PA is the clear theoretical underpinnings that outline its enhancement. These characteristics include primary and vicarious experiences, verbal persuasion, and affective/physiological states (Bandura, 1997). Previous experiences, especially those considered successful, are considered the most prominent source of self-efficacy according to Bandura. Vicarious experiences represent the potential inspiration one gets from the observations of other people's behavioral engagement. Verbal persuasion is a source of self-efficacy stemming from receiving positive feedback from others. Finally, affective and physiological states are the feelings one associates with their behavior. For example, this might be the vigor or enjoyment one links to PA. Meta-analysis studies suggest that mastery experiences, vicarious experiences, and verbal persuasion are the strongest sources for promoting PA self-efficacy (Ashford et al., 2010; Williams and French, 2011). Williams and French (2011) also highlighted the strategy of planning when, where, and how to be physically active when trying to boost self-efficacy.

While self-efficacy is arguably the most prominent self-evaluation process related to enhancing PA (McAuley et al., 2012), less is known about links between shame and PA. However, research is starting to highlight the salience of shame in undermining PA (Sabiston et al., 2010; Gilchrist et al., 2017). Emotions such as shame create multidimensional response tendencies over a relatively short period of time (Fredrickson, 2001). Emotions stem from personally meaningful appraisals of an object. For example, an individual invited to attend a new gym who anticipates experiencing scrutiny because of poor fitness is likely to avoid the situation (e.g., make up an excuse not to go). In this case, potentially losing social status in the eyes of others by showing incompetence is the object that provokes anticipated shame (Tracy and Robins, 2004). Common response tendencies associated with shame are thought to be disruptive, including avoidance, withdrawal, passiveness, and self-loathing (Gilbert, 1997; Haidt, 2003). However, some evidence suggests that shame can promote approach-oriented interpersonal responses such as cooperation and pro-social behavior (De Hooge et al., 2011).

In terms of PA, Sabiston et al. (2010) revealed that body-related shame was negatively related to leisure-time PA ($r = -0.23$) in a sample of adult women from Canada. Findings also revealed that body-related shame related to undesirable patterns of PA motivation (i.e., high controlled and low autonomous). Gilchrist et al. (2017) explored anticipated shame as a predictor of the quality and quantity of marathon training in the final 5 weeks leading up to the race. Findings revealed that anticipated shame was not associated with future time or effort spent training for the marathon. However, these participants reported very low levels of anticipated shame. The data collection timing may of also affected these results as it is common for marathon runners to reduce training (i.e., taper) in the final weeks of race preparation.

These studies provide a foundation from which to move future research on shame and PA forward. For example, Sabiston et al. (2010) focused on relations between body-related shame and PA. Future research needs to further clarify how the object focus of shame relates to PA. It is plausible that mapping the object focus of shame directly to the behavior (i.e., shame toward PA rather than shame toward body) may produce stronger relations with PA. Future research also needs to move beyond cross-sectional research designs with both men and women. Gilchrist et al. (2017) addressed both of these issues, however, their focus was on a highly active sample of adults (i.e., marathon runners) training for a competitive race. Thus, there is a clear need to examine links between shame and PA in samples that reflect broader populations of society.

## The Present Study

The purpose of this study was to investigate how self-evaluation processes operationalized as anticipated shame and exercise self-efficacy relate to young adults' weekly trajectories of moderate intensity PA behavior. The first research question (RQ1) examines the nature of change in PA over the course of 5 weeks, focusing on the initial amount of PA, trajectories of PA over time, and the relation between these two aspects of PA. RQ2 investigates the amount of inter-individual difference in both the amount of PA and its trajectory. RQ3 and RQ4 investigate the extent to which exercise self-efficacy and anticipated shame (i.e., time-varying covariates) relate to participants' PA, respectively.

# MATERIALS AND METHODS

## Participants and Procedures

The sample included young adults ($N = 71$; $M$age = 21.25, $SD = 1.18$) from a large university in the Southeastern United States. There were slightly more males ($n = 39$, 55%) than females ($n = 32$, 45%). Participants mainly reported their race/ethnicity as White, Caucasian (66%), Black, African American (21%), or Multi-Racial (4%) and were seniors (82%), juniors (10%), and sophomores (8%) in their academic rank. The researchers' Institutional Review Board provided reviewed and approved the study protocol. The researchers described the study to potential participants during one class period in a large Kinesiology course. The participants received an email with a link to an online survey each week for 5 consecutive weeks. During the first part of the first survey, participants read a passage that descried the voluntary nature of the study and provided informed consent by clicking on a button that started the survey. Each link was active for 48 h and sent to participants on each Monday morning.

## Measures

Participants completed questions about basic demographics, including age, sex, race/ethnicity, and grade classification. Exercise self-efficacy was based on an item from the Exercise Self-Efficacy Scale (McAuley, 1993): "How confident are you that you can exercise at a moderate intensity three times per week for at least 40+ min for the next week?" The answer scale ranged from 0% (not at all confidence) to 100% (highly confidence) using 10% intervals. Shame (Gilchrist et al., 2017) was measured with the following item "How ashamed will you feel if you do not meet your exercise goal this week?" on a scale ranging from 1 (not at all) to 5 (extremely). Finally, participants reported the number of days in the previous week they exercised for at least 40 min at a moderate intensity. This question was based on the Global Physical Activity Questionnaire developed by the World Health Organization (2005).

## Data Analysis

Preliminary analyses included examination of missing data, variable distribution patterns, descriptive statistics, and correlation estimates. In order to evaluate our main research questions, we tested a series of latent growth curve models within the structural equation modeling framework using Mplus version 7.4 (Muthén and Muthén, 2017). All models used maximum likelihood estimation procedures. Missing data were handled with full information likelihood estimation (FIML) procedures (Enders, 2010). Model fit was judged using chi-square estimates based on degrees of freedom, comparative fit index (CFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and standardized root mean residuals (SRMR). For CFI and TLI, higher scores reflect better model to data fit with criteria of a good fit, ≥0.95, and acceptable fit, ≥0.90 (Hu and Bentler, 1999). For RMSEA and SRMR, lower scores represent better model to data fit with criteria of a good fit, ≤0.06, and acceptable fit, ≤0.08 (Hu and Bentler, 1999).

We started by testing unconditional latent curve models for moderate PA. Specifically, we tested a series of trajectories, including an intercept only model (i.e., no growth), linear trajectory, quadratic trajectory, and finally a latent basis trajectory. Time (i.e., slope) was coded as 0, 1, 2, 3, and 4 in the linear model. In the quadratic model, time was coded as 0, 1, 4, 9, and 16 in addition to the linear slope. Finally, in the latent basis model, time was coded 0 at T1 and 1 and T5, while T2–T4 were freely estimated (Ram and Grimm, 2007). Residual variance estimates were constrained to be equal across the five waves of data. We treated PA as a continuous variable because it had more than five categories and it was normally distributed (Sass et al., 2014; see **Table 1**).

We then added both time-invariant and time-varying covariates. Specifically, sex (male = 1, female = 0) was added as a time-invariant predictor of PA, while anticipated feelings of shame and exercise self-efficacy were added as time-varying covariates. We ran two conditional models, the first whereby time-varying covariates were estimated at each time point, and the second whereby equality constraints were added to each time-varying covariate in order to obtain the standardized relationship for each covariate with the PA trajectory.

# RESULTS

## Preliminary Findings

There were 322 time specific observations across the five waves of data. Approximately 82% of the participants completed all five waves of data, 12% four waves, 4% two waves, and 2%

**TABLE 1** | Descriptive statistics for all study variables.

| | Total | | Males | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** | **Min** | **Max** | **Skew** | **Kurtosis** |
| Week 1 PA | 3.14 | 1.88 | 3.63 | 1.86 | 2.56 | 1.76 | 0 | 7 | 0.09 | −0.43 |
| Week 2 PA | 3.36 | 1.80 | 3.76 | 1.67 | 2.94 | 1.86 | 0 | 7 | −0.04 | −0.41 |
| Week 3 PA | 3.23 | 1.59 | 3.58 | 1.60 | 2.87 | 1.52 | 0 | 7 | 0.06 | −0.26 |
| Week 4 PA | 3.18 | 1.77 | 3.86 | 1.54 | 2.44 | 1.74 | 0 | 7 | 0.14 | −0.52 |
| Week 5 PA | 3.32 | 1.65 | 3.94 | 1.56 | 3.62 | 1.50 | 0 | 7 | −0.20 | −0.26 |
| Week 1 Shame | 1.74 | 0.86 | 1.76 | 0.75 | 1.72 | 0.99 | 1 | 5 | 1.36 | 2.33 |
| Week 2 Shame | 1.80 | 0.95 | 1.76 | 0.89 | 1.84 | 1.01 | 1 | 5 | 1.19 | 1.15 |
| Week 3 Shame | 1.74 | 0.73 | 1.73 | 0.76 | 1.75 | 0.72 | 1 | 5 | 0.70 | 0.06 |
| Week 4 Shame | 1.84 | 0.99 | 1.77 | 1.00 | 1.91 | 0.99 | 1 | 5 | 1.10 | 0.07 |
| Week 5 Shame | 1.95 | 1.11 | 1.91 | 1.10 | 2.00 | 1.03 | 1 | 5 | 1.11 | 0.63 |
| Week 1 ESE | 7.61 | 2.58 | 8.34 | 2.00 | 6.75 | 2.94 | 0 | 10 | −0.75 | −0.80 |
| Week 2 ESE | 7.39 | 2.86 | 8.26 | 2.60 | 6.47 | 2.87 | 0 | 10 | −0.59 | −1.23 |
| Week 3 ESE | 7.40 | 2.77 | 8.42 | 2.21 | 6.34 | 2.92 | 0 | 10 | −0.69 | −0.80 |
| Week 4 ESE | 6.88 | 3.00 | 7.86 | 2.74 | 5.81 | 2.94 | 0 | 10 | −0.42 | −1.23 |
| Week 5 ESE | 7.10 | 2.72 | 8.12 | 2.34 | 5.93 | 2.70 | 0 | 10 | −0.41 | −1.16 |

*PA, average number of days per week of 40+ min of moderate physical activity; ESE, exercise self-efficacy.*

one wave. The amount of missing data at each time was: (a) week 1, 1%, (b) week 2, 7%, week 3, 8%, week 4, 5%, and week 5, 12%. Reports of PA produced normal distribution properties at each time point (see **Table 1**). **Table 1** presents descriptive statistics for all study variables. These young adults reported engaging in 40 min of moderate PA approximately 3 days per week. Reports of shame were below the midpoint of its scale in all five waves of data whereas reports of exercise self-efficacy were above the midpoint of its scale in all five waves of data. A correlation matrix is provided in **Table 2**. In general, there were positive, moderate relations between PA and exercise self-efficacy at each time point. There were negative, weak-to-moderate relations between PA and shame at each time point.

## Main Findings

**Table 3** provides results from unconditional latent growth curve model testing. Our findings revealed that the linear latent growth curve model for PA fit these data better than the intercept-only model ($\Delta CFI = 0.051$), and fit these data equally well compared to the more complex quadratic and latent models. Therefore, we used the linear model for subsequent analyses. The overall fit was acceptable although the RMSEA estimate was slighter higher than recommended values (Hu and Bentler, 1999). **Table 3** highlights parameter estimates of the linear latent growth curve model for PA. The latent intercept mean revealed that the predicted level of participants' PA consisted of engaging in 40 min of moderate intensity PA on 3.187 days during week 1 with meaningful variance around the mean. The latent slope mean estimate was not statistically significant, suggesting that on average PA trajectories were stable across the 5-week period. However, the linear slope variance estimate underscored heterogeneity in the PA trajectories. The negative covariance between the intercept and linear slope implies that participants' reporting more days of PA at week 1 experienced a slower rate of change compared to participants reporting fewer days of PA at week 1.

Model fit results from the conditional models, which included sex (male = 1, female = 0) as a time-invariant covariate, and shame and exercise self-efficacy as time-varying covariates are provided at the bottom of **Table 3**. We tested two conditional models; the free conditional model estimated shame and exercise self-efficacy freely at each of the five time points while the standardized model placed equality constraints on shame and exercise self-efficacy, respectively, in order to examine the systematic relations across time. Adding these equality constraints produced a similar fitting model compared to the freely estimated model. Therefore, we focus on the standardized model while addressing RQ3 and RQ4. The overall model fit was adequate, with only the TLI estimate (0.898) slightly below the recommended guideline of 0.90 (Hu and Bentler, 1999). Sex was not associated with participants' predicted level of PA at week 1 or its rate of change (see **Table 4**). Support of the standardized model suggested that the time-varying covariates were stable across individual time points. A one-unit increase in shame was associated with a 0.225 decrease in PA during any given week whereas a one-unit increase in exercise

**TABLE 2** | Correlation matrix for all study variables.

| | ESE_T1 | Shame_T1 | PA_T1 | ESE_T2 | Shame_T1 | PA_T2 | ESE_T3 | Shame_T3 | PA_T3 | ESE_T4 | Shame_T4 | PA_T4 | ESE_T5 | Shame_T5 | PA_T5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESE_T1 | 1 | | | | | | | | | | | | | | |
| Shame_T1 | −0.377** | 1 | | | | | | | | | | | | | |
| PA_T1 | 0.670** | −0.459** | 1 | | | | | | | | | | | | |
| ESE_T2 | 0.832** | −0.331** | 0.530** | 1 | | | | | | | | | | | |
| Shame_T2 | −0.245* | 0.556** | −0.19 | −0.226 | 1 | | | | | | | | | | |
| PA_T2 | 0.520** | −0.422** | 0.612** | 0.598** | −0.236 | 1 | | | | | | | | | |
| ESE_T3 | 0.781** | −0.291* | 0.608** | 0.786** | −0.332** | 0.448** | 1 | | | | | | | | |
| Shame_T3 | −0.370** | 0.396** | −0.243 | −0.323** | 0.542** | −0.294* | −0.331** | 1 | | | | | | | |
| PA_T3 | 0.547** | −0.258* | 0.677** | 0.510** | −0.028 | 0.678** | 0.507** | −0.215 | 1 | | | | | | |
| ESE_T4 | 0.739** | −0.279* | 0.541** | 0.702** | −0.237 | 0.401** | 0.772** | −0.304* | 0.403** | 1 | | | | | |
| Shame_T4 | −0.346** | 0.549** | −0.367** | −0.327** | 0.485** | −0.264* | −0.316* | 0.611** | −0.142 | −0.321** | 1 | | | | |
| PA_T4 | 0.526** | −0.243* | 0.563** | 0.424** | −0.166 | 0.530** | 0.473** | −0.154 | 0.549** | 0.578** | −0.249* | 1 | | | |
| ESE_T5 | 0.711** | −0.277* | 0.653** | 0.760** | −0.318* | 0.479** | 0.786** | −0.399** | 0.514** | 0.779** | −0.380** | 0.573** | 1 | | |
| Shame_T5 | −0.296* | 0.339** | −0.268* | −0.148 | 0.450** | −0.157 | −0.176 | 0.582** | −0.148 | −0.286* | 0.688** | −0.317* | −0.298* | 1 | |
| PA_T5 | 0.433** | −0.127 | 0.542** | 0.326* | −0.117 | 0.401** | 0.421** | −0.155 | 0.485** | 0.438** | −0.267* | 0.752** | 0.610** | −0.289* | 1 |

*PA, average number of days per week of 40+ min of moderate physical activity; ESE, exercise self-efficacy; T1, time 1.*p < 0.05; **p < 0.01.*

**TABLE 3** | Latent growth model fit statistics.

| Model | $\chi^2$ | *df* | CFI | TLI | RMSEA | SRMR |
|---|---|---|---|---|---|---|
| Physical activity | | | | | | |
| Intercept only | 34.527** | 17 | 0.897 | 0.939 | 0.121 | 0.114 |
| Linear | 22.882 | 14 | 0.948 | 0.963 | 0.095 | 0.079 |
| Quadratic | 20.237* | 10 | 0.940 | 0.940 | 0.120 | 0.097 |
| Latent | 19.892* | 11 | 0.948 | 0.952 | 0.107 | 0.102 |
| Conditional free | 73.520* | 53 | 0.901 | 0.879 | 0.082 | 0.047 |
| Conditional standardized | 80.879* | 61 | 0.904 | 0.898 | 0.075 | 0.065 |

*Intercept only model represents a "no growth" model; linear, linear slope with time coded 0, 1, 2, 3, and 4. Quadratic model includes linear and quadratic slopes with quadratic slope coded 0, 1, 4, 9, and 16. Latent model coded 0 at T1 and 1 at T5 while T2–T4 are estimated. Bottom part of table reflects. Latent growth models with covariates. In the free model, time varying covariates are estimated at each time point. In standardized model, time varying covariates are constrained to be equal across five time points.*
*$^*p < 0.05$: $^{**}p < 0.01$.*

self-efficacy was associated with a 0.279 increase in PA during any given week (see **Table 4**). The $R^2$ values for PA at each week in the final model were: (a) week 1, 0.676; (b) week 2, 0.616; (c) week 3, 0.597; (d) week 4, 0.683, and (e) week 5, 0.816. The $R^2$ values for latent intercept and slope were small, 0.037 and 0.010, respectively.

# DISCUSSION

The purpose of this study was to investigate how self-evaluation processes relate to young adults' weekly trajectories of moderate intensity PA behavior. Specifically, we examined four research questions related to PA trajectories (RQ1 and RQ2) and self-evaluation covariates (exercise self-efficacy, RQ3; anticipated shame, RQ4) over a 5-week period using latent growth modeling. Young adults, especially those who enroll in universities, are one segment of the population that typically experiences declines in PA (Kwan et al., 2012) and often fail to meet recommended levels of PA (Farren et al., 2017; American College Health Association, 2020). Major findings revealed considerable variation in young adults starting levels and trajectories of PA as well as consistent positive relations with exercise self-efficacy and inconsistent negative relations with anticipated shame.

## Weekly Trajectories of PA

RQ1 and RQ2 focused on young adults PA. Regular PA is an essential strategy for maximizing health and reducing modifiable risks causing morbidity and mortality (United States Department of Health and Human Services, 2018). Young adults attending university are especially vulnerable for experiencing declines in PA (Maselli et al., 2018). Findings from this study illustrate PA patterns in a sample of young adults from a region in the United States with consistently higher rates of sedentary behavior and obesity (Centers for Disease Control and Prevention, 2020). According to the United States Department of Health and Human Services (2018) adults should be active most days per week. On average, the participants in this study reported being active approximately 3 days per week with trajectories that stayed stable across the 5 weeks of the study. However, there was heterogeneity in both the initial levels and weekly trajectories of these young adults PA. Furthermore, young adults who reported more days of PA at baseline were more likely to see slower rates of change across the 5-week period. Although not directly comparable, these participants reported slightly lower amounts of PA compared to previous studies measuring young adults PA using accelerometers (Henderson et al., 2020).

The heterogeneity in our participants' initials levels and rates of change in PA yield insights that can guide promotion strategies of short-term PA in young adults. Specifically, the variation in initial levels and trajectories of PA suggest the need for deliberate target strategies for young adult subgroups. Interestingly, our findings revealed that it is not as simple as targeting males or females. Previously effective strategies for university students include tailoring interventions to current levels of PA (Keating et al., 2005). For example, strategies for young adults who are completely sedentary would be different from strategies for those who participate in some PA. Furthermore, exploring profiles of specific sets of salient barriers toward PA may also help create more fine-tuned PA targeting. For example, young adults who report low levels of social support may need different intervention strategies than those who lack safe, accessible PA infrastructure.

Finally, offering university courses that promote health education and provide young adults with structured PA opportunities on a weekly basis may also help reduce the variability seen in this study. Adherence to PA is influenced by numerous factors, however, structure and supervision are often highlighted as key elements (Gilli et al., 2018). Unfortunately, many universities in the United States do not require students to enroll in personal health courses. Recent estimates suggest that only about 10% of universities in the United States required a personal health course in order for students to graduate (Henry et al., 2017).

## Self-Evaluation Predictors

Self-efficacy and shame share foundations grounded in self-evaluation (Baldwin et al., 2006). While self-efficacy has been widely acknowledged as a key determinant of PA (Dishman et al., 2004; Maddison et al., 2014), less research has examined the role of shame in shaping one's PA. Findings from our study provide greater insights concerning self-efficacy (RQ3), shame (RQ4), and young adults' short-term PA trajectories. Exercise self-efficacy was a consistent, positive predictor of PA

**TABLE 4 |** Parameter estimates for linear latent growth models.

| Parameter-unconditional | I mean | I variance | S mean | S variance | I S covariance | I S correlation |
|---|---|---|---|---|---|---|
| PA | 3.187 (0.210)** | 2.467 (0.527)** | 0.025 (0.054) | 0.088 (0.035)* | −0.204 (0.110)* | −0.533* |
| Parameter-conditional | | | | | | |
| Physical activity | 1.018 (0.439)** | 1.178 (0.338)** | 0.035 (0.080) | 0.104 (0.036)** | −0.214 (0.094)* | −0.631* |
| Covariates | B (SE) | β | | | | |
| I on Male | 0.424 (0.359) | 0.192 | | | | |
| S on Male | 0.061 (0.112) | 0.094 | | | | |
| PA_1 on ESE_1 | 0.369 (0.063)** | 0.510 | | | | |
| PA_1 on Shame_1 | −0.503 (0.173)* | −0.241 | | | | |
| PA_2 on ESE _2 | 0.305 (0.053)** | 0.491 | | | | |
| PA_2 on Shame_2 | −0.229 (0.149) | −0.127 | | | | |
| PA_3 on ESE _3 | 0.261 (0.047)** | 0.434 | | | | |
| PA_3 on Shame_3 | −0.154 (0.164) | −0.068 | | | | |
| PA_4 on ESE _4 | 0.258 (0.047)** | 0.454 | | | | |
| PA_4 on Shame_4 | −0.183 (0.128) | −0.127 | | | | |
| PA_5 on ESE_5 | 0.229 (0.057)** | 0.388 | | | | |
| PA_5 on Shame_5 | −0.139 (0.132) | −0.111 | | | | |
| PA on ESE_ave | 0.279 (0.040)** | 0.413, 0.482 | | | | |
| PA on Shame_ave | −0.225 (0.093)* | −0.098, −0.146 | | | | |

*I, latent intercept; S, latent slope; PA, average number of days per week of 40+ min of moderate physical activity; ESE, exercise self-efficacy; B (SE), unstandardized beta coefficient with standard error; β, standardized beta coefficient. Ave, unstandardized beta average estimate across all five time points. *p < 0.05; **p < 0.01.*

at each of the five time points and on average across time. These results reinforce the importance of addressing one's self-efficacy when considering the promotion of health behavior (Bandura, 2004). Therefore, targeting sources of self-efficacy represents a key consideration when developing PA interventions with young adults (Bandura, 1997; Ashford et al., 2010; Williams and French, 2011). However, findings from meta-analysis studies on enhancing self-efficacy toward PA specifically highlight divergences from standard suggestions of mastery experiences, verbal persuasion, vicarious experiences, and physiological/affective states of Bandura (1997).

In terms of mastery experience, which Bandura (1997) highlights as the most critical source of self-efficacy, Ashford et al. (2010) found that intervention techniques that used feedback on past performance was an especially successful strategy for enhancing one's exercise self-efficacy. Similarly, Williams and French (2011) reported that feedback focused on effort or PA progress to be an effective strategy for enhancing exercise self-efficacy. Thus, developing PA environments that focus on feedback geared toward personal improvement and success appears warranted. However, both of these meta-analysis studies revealed that grading performance to mastery criteria actually lowered one's exercise self-efficacy.

Interestingly, in the Ashford et al. (2010) meta-analysis, PA interventions that used vicarious experiences generally increased self-efficacy while persuasion techniques were associated with decreases in exercise self-efficacy. Thus, there appear to be nuances regarding how sources of self-efficacy can be implemented effectively in PA interventions. One of the most interesting findings from the Williams and French (2011) meta-analysis was the potential strength of using action planning techniques in PA interventions. Action planning is a self-regulation strategy aimed at creating if-then plans that help link environmental cues to behavioral responses (Conner et al., 2010). These if-then plans typically focus on addressing specific details about how, when, and where PA will occur as well as identifying contingences if/when barriers arise. Williams and French (2011) reveal that the use of action plan strategies in PA interventions enhance exercise self-efficacy and increased levels of PA. Therefore, future research should explore action planning techniques in health-related interventions because of their potential to facilitate both cognitive determinants and behavior.

Shame produced an inconsistent pattern of relationships with PA compared to exercise self-efficacy. Specifically, it was a negative predictor of PA at T1 and on average across the 5 weeks. However, it was not a significant predictor at T2, T3, T4, or T5. Our results produced both similarities and differences compared to previous research. For example, on average, participants in this study reported low levels of shame, similar to previous research with adult women (Sabiston et al., 2010) and runners training for a marathon (Gilchrist et al., 2017). The negative direction and low magnitude of the relationship between shame and PA was similar to findings from Sabiston et al. (2010). However, the average relations between shame and PA across time were a unique finding, diverging from results reported by Gilchrist et al. (2017). This is likely a reflection of differences in sample characteristics (i.e., somewhat active young adults versus adults in the final stages of marathon training).

Theorists suggest emotions produce predictable action tendencies over short periods of time (Fredrickson, 2001) with shame facilitating avoidance behaviors (Haidt, 2003). Unlike broader measures of affect, discrete emotions such as shame always have a specific object focus (Pekrun, 2006). In this study, the object focus of shame was not meeting one's exercise goal for the week. The personal nature of an exercise goal may help explain the low magnitude in relation between shame and PA. Future researchers should consider creating a normative object focus of PA related shame such as failing to meet important others' expectations or losing social status. It is possible that the normative implications of PA related shame may increase the magnitude of avoidance tendencies. In many instances, PA environments can facilitate social comparisons that lead to negative thoughts and feelings in young adult populations (Fitsimmons-Craft et al., 2016). In simple terms, using a normative object focus may increase the stakes related to one's anticipated negative outcomes.

It is important to acknowledge limitations associated with this study. First, because of the repetitive nature conducting weekly data collections, we used one-item measures of all study variables to reduce participant burden. Despite robust auto-correlations across time (i.e., test-retest) for all variable (see **Table 2**), this is not an ideal measurement approach. Future researchers should use more comprehensive measures of exercise self-efficacy, shame, and PA. Second, we examined young adults' weekly trajectories of PA. This short-term timeline reflects the theorized properties of emotional effects (Fredrickson, 2001) and follows previous studies on shame (Gilchrist et al., 2017), but may not generalize to long-term PA. Examination of longer measurement intervals is needed in future research. Third, we used a small sample of young adults from one university in one region of the United States. Future studies would benefit from examining self-evaluation and PA in diverse samples. Finally, we relied on self-report measures of PA, which may produce social desirability bias. Future research should use objective measures of PA such as accelerometers.

## CONCLUSION

The purpose of this study was to examine young adults' weekly trajectories of PA, exploring exercise self-efficacy and anticipated shame as time varying predictors. Our findings demonstrated considerable variability in these young adults reports of PA at the beginning of the study and trajectories across time. Results also highlighted the positive and negative sides of PA self-evaluations. Self-efficacy continues to be one of the most consistent enhancers of PA, making it a strategic factor when considering future health-related interventions with young adults. Feelings of shame represented a barrier to these young adults' PA, although its impact did not appear overly deleterious. Nevertheless, addressing situational factors that cause PA related shame needs greater examination in order to maximize young adults' participation in health-enhancing PA.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Louisiana State University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

AG helped conceptualize the study, analyzed the data, and contributed to the writing of the manuscript. KS helped conceptualize the study, collected the data, and contributed to the writing of the manuscript. All authors contributed to the article and approved the submitted version.

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# Antecedents and Consequences of Outward Emotional Reactions in Table Tennis

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The purpose of the present study was to shed light on the behavioral component of emotions by investigating antecedents and consequences of outward emotional reactions during table tennis competitions. With regards to the antecedents of outward emotional reactions, in line with appraisal theories, we considered the importance and the controllability of the situation as two important constructs. Fifteen table tennis matches, involving in total 21 players (7 females) with a mean age of 16.71 ($SD$ = 0.70), were video recorded during the finals of the youth National Championship in Greece. Based on the footage, outward emotional reactions after every point were classified as neutral, positive, or negative. Situational factors in relation to the scoring system, bearing the importance and the controllability of the situation, were formed to assess antecedents of outward emotional reactions. To measure the consequences of outward emotional reactions, the impact on the outcome of the next point was assessed. Generalized linear models with a logit link were computed separately for positive outward emotional reactions after having won a point and negative outward emotional reactions after having lost a point. In general, the results show that while situational factors bearing the importance of the situation could predict positive and negative outward emotional reactions, the effects of situational factors bearing the controllability of the situation were less conclusive. In addition, the results also showed interactive effects between the two constructs for both positive and negative outward emotional reactions. With regard to the consequences of outward emotional reactions, negative and positive outward emotional reactions could not predict the outcome of the next point. To conclude, this study highlights the behavioral component of emotions as a viable alternative to enhance our understanding of the role of emotions in sport.

**Keywords: emotion, importance, controllability, behavior, observation**

## INTRODUCTION

In sports like table tennis, players can react very differently, depending on whether they won or lost a point. In some situations, after having won a point, players may make a fist and give a shout of joy, whereas after losing a point, players might throw the racket and give a shout of frustration. In other situations, however, you cannot really tell from the players' reaction whether the point was won or lost. This variety of emotional reactions during a match not only makes sport fascinating to watch, it also says a lot about the psychological challenges players face in sports competitions.

Emotions are an integral part of sports. This is highlighted by studies in general psychology that make use of the nature of sports competitions to study emotions (e.g., Fernández-Dols and Ruiz-Belda, 1995; Matsumoto and Willingham, 2006; Aviezer et al., 2012). Although the definition of emotions is highly debated (Lindquist et al., 2013), researchers agree that emotions consist of one's individual subjective experience (e.g., feeling anxious), physiological processes (e.g., change in blood pressure), and behavioral component (e.g., facial expressions; Mauss and Robinson, 2009). Research aimed at understanding the role of emotions in sports has mostly utilized questionnaires (e.g., Jones et al., 2005), or interviews (Martinent and Ferrand, 2009). Due to ethical and practical reasons, these methods cannot be applied to investigate emotions in real time, i.e., *during* real sports competitions, and thus limit the ecological validity of retrospective or prospective study designs (Uphill et al., 2014). As an alternative to these methods, focusing primarily on the subjective experience of emotions or the *perception* of physiological processes, this study was based on the premise that emotions are also observable from the outside. The behavioral component of emotion is worth investigating as it is relatively understudied, but also as it addresses the interpersonal nature of emotions (Tamminen and Bennett, 2017). Specifically, in this study we focused on the investigation of antecedents and consequences of outward emotional reactions in table tennis.

The term *outward emotional reaction* refers to an impression, which is based on an individual's behavior and provides information about his/her emotional state. This impression includes different body signals that indicate an emotional state. Examples of these are postures, gestures, facial expressions, and verbalizations (Mauss and Robinson, 2009). It is important to note that instead of focusing on discrete emotions such as joy or anger, outward emotional reactions generally distinguish between positive and negative reactions, which makes it possible to study a wide range of emotions (Ekkekakis, 2013). While negative outward emotional reactions indicate that something emotionally unpleasant has happened to the individual (e.g., losing a point), positive outward emotional reactions indicate that something emotionally pleasant has occurred to the individual (e.g., scoring a point). It is further important to note that outward emotional reactions do not always correspond to the subjective emotions experienced. On the one hand, players sometimes fake a higher emotional intensity than is actually experienced through outward emotional reactions (Sève et al., 2007). On the other hand, even intense emotions experienced are not always accompanied by outward emotional reactions (Fernández-Dols and Ruiz-Belda, 1995).

From a sport psychological perspective, two intriguing questions arise: (a) under which conditions are outward emotional reactions more likely to occur and (b) how do these subsequently affect sports performance? In other words, it appears fruitful to focus on the antecedents and consequences of outward emotional reactions in sport competitions (Hanin, 2007). Expanding metacognitive knowledge about these two aspects could help players to regulate their behavior and thoughts more effectively and could thus also improve their emotion regulation skills (MacIntyre et al., 2014). Understanding the conditions under which players tend to react emotionally and identifying how these reactions affect sports performance can help us understand the underlying psychological processes. In addition, such knowledge could be used to develop strategies that channel emotions in a performance-enhancing way, both proactively and reactively (Uphill and Jones, 2007).

In sports like table tennis or tennis, winning or losing a point are the proximate events that trigger outward emotional reactions. Outward emotional reactions, however, are not randomly distributed throughout a match. In line with theoretical appraisal emotion approaches (Lazarus, 1991; Scherer, 2013), the importance of the situation and the controllability of the situation appear to be two relevant constructs that can either increase or decrease the likelihood of outward emotional reactions. These constructs do not themselves elicit outward emotional reactions, however, they may regulate the occurrence of outward emotional reactions following a potentially emotion-eliciting stimulus (i.e., winning or losing a point in table tennis). Because emotions are the result of a person-environment transaction (Lazarus, 1991), it is important to understand the subjective appraisal processes (e.g., Uphill and Jones, 2007). However, studies in tennis and table tennis have showed that these appraisal processes are often related to situational factors, such as the scoring system (Sève et al., 2007; Lewis et al., 2017). Since such situational factors can be objectively classified in observational studies, they appear to be particularly useful for studying their relationship to outward emotional reactions (for a study in handball see Moesch et al., 2015).

The importance of the situation hugely depends on the potential consequences it can have. Situations with more significant consequences for the individual's goal attainment are associated with stronger emotional responses (Lazarus, 1991; Scherer, 2013). The importance of the situation is appraised very rapidly after the occurrence of an either positive or negative stimulus, and directs more in-depth processing (Scherer, 2013). Moesch et al. (2015) showed, for example, that handball players were more likely to celebrate a goal openly (i.e., positive outward emotional reactions) in elimination matches than in group stage matches. A possible explanation for this is that a defeat in elimination matches is equivalent to an elimination from the competition, which makes the situation more significant. In contrast, a defeat during a group stage match might be potentially compensated by subsequent matches. Because table tennis matches are divided into sets and sets in turn are divided into points, the importance can also be leveled down to the set level (within the match) as well as the point level (within the set). While points/sets closer to the potential end of a set/match have a stronger impact on the outcome of the set/match, earlier points/sets in the set/match can be compensated more easily by future actions.

The controllability of a situation refers to a basic psychological need, as people generally prefer to have control over the potential outcomes of a situation (Ryan and Deci, 2000). In comparison to the importance of the situation, which must be identified beforehand, the controllability of a situation is appraised at a later stage (Scherer, 2013). In addition, the controllability of a situation seems to be more important for stimuli that are incongruent with the current goal (Scherer, 2013). Since positive emotions are viewed as benefiting one's goals (Lazarus, 1991), situational factors associated with the controllability of a situation could in particular influence the occurrence of negative outward emotional reactions. In table tennis, the current score is one relevant situational factor in relation to emotions (Sève et al., 2007). In situations where the players are leading, the controllability of the situation is higher than in situations where the players are trailing. Hence, the current score can be an indicator of controllability. Table tennis sets generally have 11 points. Leading by 9 to 2 points in a set indicates a higher controllability than leading by 9 to 8 points. At the same time, being behind by 2 to 9 points is associated with a lower controllability of the situation than being behind by 8 to 9 points. Furthermore, the controllability of the situation can be influenced by preceding experiences (Bandura, 1997). Winning consecutive points can lead to a positive momentum that in turn is related to a higher controllability of the situation (Kimiecik and Jackson, 2002). In contrast, losing consecutive points can lead to a negative momentum and is thus related to a lower controllability of the situation.

Summarizing the above we argue that a higher importance of the situation generally increases the likelihood of both positive and negative outward emotional reactions. Furthermore, a higher controllability of the situation generally decreases the likelihood of negative outward emotional reactions. As these constructs do not function in isolation during a sports competition, it is important to consider the interactive effects of their associated situational factors. For instance, losing a point when the score is 9-7 is related to a higher level of importance of the situation, which thus increases the likelihood of negative outward emotional reactions (Lazarus, 1991; Scherer, 2013). However, at the same time, being in front (9-7) increases the controllability of the situation, and thus decreases the likelihood of negative outward emotional reactions. On the contrary, losing a point at the end of the set when you are behind (7-9) can accumulate effects of a higher importance/lower controllability of the situation, making negative outward emotional reactions very likely.

From a sport psychological perspective, it is not only interesting to understand why players show outward emotional reactions in some situations and not in others, but also how these in turn affect the subsequent sports performance. Enhancing the understanding of the relationship between emotions and sports performance can raise players' awareness of the importance of applying appropriate emotion regulation strategies (Jones, 2003). A number of studies have investigated outward emotional reactions (e.g., over verbalizations and gestures) and have linked these to objective performance indicators (e.g., the subsequent point). Studies in tennis have yielded interesting yet inconsistent results. While two studies showed an association between negative outward emotional reactions and a reduced probability of winning the next point (Van Raalte et al., 1994; Zourbanos et al., 2015), another study could not replicate this finding (Van Raalte et al., 2000). Conversely, it was shown that positive outward emotional reactions either have only a very weak positive association with the outcome of the next point (Van Raalte et al., 2000; Zourbanos et al., 2015) or no association at all (Van Raalte et al., 1994).

In this article, we argue that investigating outward emotional reactions can contribute to our understanding of the role of emotions in sports. The purpose of this study was to study emotions in real time and in their natural context by investigating antecedents and consequences of outward emotional reactions. In particular, we examined situational factors associated with the importance of the situation and the controllability of the situation as two important constructs influencing emotional outcomes (Lazarus, 1991; Scherer, 2013). With regard to antecedents of outward emotional reactions, we hypothesized that situational factors bearing a higher importance of the situation (e.g., point at the end of the set) would increase the likelihood of both positive outward emotional reactions after winning a point as well as negative outward emotional reactions after losing a point. In line with the assumption that the controllability of a situation has a greater effect for goal incongruent stimuli (Scherer, 2013), we also hypothesized that situational factors bearing a higher controllability of the situation (e.g., leading) would reduce the likelihood of negative outward emotional reactions after losing a point. For positive outward emotional reactions after winning a point, we hypothesized that the controllability of the situation would not have an effect. In addition, we hypothesized that the increased probability of negative outward emotional reactions in highly important situations would be reduced when there was a higher controllability of the situation (e.g., leading at the end of the set). For positive outward emotional reactions, we hypothesized that there would be no interaction between the importance and the controllability of the situation. With regards to the consequences of outward emotional reactions, the subsequent point was taken as a performance indicator. Given the inconsistent results of previous studies (Van Raalte et al., 1994, 2000; Zourbanos et al., 2015), we did not have specific hypotheses regarding the impact of positive and negative outward emotional reactions on the likelihood of winning the next point.

## MATERIALS AND METHODS

### Participants

Participants were approached before the finals of the Greek national youth championship. A total of 14 male and 7 female Greek junior table tennis players, aged 16 to 18 years ($M$ = 16.71; $SD$ = 0.70) and with an average of 7.29 ($SD$ = 1.72) years of competition experience agreed to participate in the study. The highest level of competition participation was international for 12 players and national for 9 players. The players trained 3.71 days (*SD* = 1.48) on average per week.

## Procedure

The university's ethics committee gave its approval for the study. Players who were 18 signed a consent form, whereas for younger players the consent was granted by their legal guardians. In order to avoid self-presentation biases, the players were told before the match that the recording was intended for motion analysis. After the tournament, they were informed about the actual objective of the study. A total of 15 matches were recorded by two cameras positioned diagonally behind the table, which recorded the movements of the players on the opposite side. Thus, the video footage showed the whole person, including postures, gestures, facial expressions, and verbalizations, as important signals for the emotional state (Mauss and Robinson, 2009). In addition, the video footage also contained the trajectories of the ball, which allowed to keep track of the score. The data collection involved eight group stage matches, one quarter-final, four semi-finals, and two finals. Some of the players took part in more than one match, and a total of 2014 points (per match: 51 to 117; *M* = 67.13; *SD* = 17.6) were observed.

## Measures

### Outward Emotional Reactions

Outward emotional reactions were used as a dependent variable to investigate their antecedents, and as an independent variable to investigate their consequences. Based on the video footage, two coders independently classified the players' reactions after each point into (1) a positive outward emotional reaction, (2) a negative outward emotional reaction, or a (3) neutral outward emotional reaction. The first coder was a researcher with expertise in emotion literature and the second one a former Greek professional table tennis player and currently a coach. The coding was based on different body signals such as postures, gestures, facial expressions, and verbalizations, indicating the players' emotional state (Mauss and Robinson, 2009). Since research suggests that conclusions about an individual's emotional state cannot be drawn from physical features alone, but rather depend on context (Kayyal et al., 2015), the outcome of the point was taken as relevant context information. The coders were instructed to code outward emotional reactions as positive when the players' behavior indicated that something emotionally positive occurred, and as negative if the players' behavior indicated that something emotionally negative happened. Considering that individuals are always in some kind of emotional state (Russell, 2009), if the coders could not tell from the behavior of the players that something emotionally positive or negative occurred, these outward emotional reactions were coded as neutral.

### Antecedents of Outward Emotional Reactions

#### *Importance of the situation*

Three situational factors representing the importance of the situation were analyzed, namely the stage of competition, the number of remaining sets, and the number of remaining points.

*Stage of competition.* This variable was used to distinguish between matches that could be compensated by future matches, and matches that were decisive for remaining in the tournament, i.e., group stage and elimination matches. Thus, points in elimination matches would indicate a higher importance of the situation than points in group stage matches. This situational factor was coded as a binary variable, with elimination matches coded as '1' and group stage matches coded as '0'.

*Remaining sets.* This variable was used to indicate the lowest number of sets that potentially had to be played until the end of a match. The lower the number of remaining sets, the more important the situation was. Thirteen of the 15 matches were played until one player had won three sets. Two matches (one final and one semi-final) were played until one player had won four sets. This situational factor was coded as a continuous variable, with a higher number indicating that potentially more sets had to be played until the end of the match.

*Remaining points.* This variable was used to indicate the lowest number of points that potentially had to be played until the end of a set. The lower the number of remaining points, the higher the importance of the situation was. The sets of all matches were played until one player had won 11 points, with at least two points difference between the players. Thus, with a score of 10-10, the set lasted at least up to 12 points (in case of a score of 11-11, up to at least 13 points, etc.). This situational factor was coded as a continuous variable, with a higher number indicating that potentially more points had to be played until the end of the set.

#### *Controllability of the situation*

Four situational factors were used to assess the controllability of the situation, namely leading in sets, leading in points, consecutive points won, and consecutive points lost. Furthermore, the two situational factors set difference and point difference were formed. However, it is important to note that these two variables only took into account the absolute set/point difference between the players, and could not distinguish whether the players were leading or not. Because this made an important difference in terms of controllability, two interaction effects (*set difference x leading in sets* and *point difference x leading in points*) were additionally analyzed.

*Leading in sets.* This variable was used to distinguish between situations where the players were leading in sets within a match and situations where the players were not leading (either trailing or tied). Trailing and tie were combined into one category because a tie implies a set difference of '0'. Treating a tie as a separate category would have therefore resembled the variable set difference (see below), which would have led to collinearity and exclusion of this category. Leading in sets would thus indicate a higher controllability of the situation. This situational factor was coded as a binary variable, with leading coded as '1' and trailing/tie coded as '0'.

*Leading in points.* This variable was used to distinguish between situations where the players were leading in points within a set, and situations where the players were not leading (either trailing or tied). The reason for combining trailing and tie was the same as described for the variable lading in sets (i.e., a tie would have resembled a point difference of '0'). Equivalent to the situational factor leading in sets, leading in points would indicate a higher controllability of the situation. This situational factor was coded as a binary variable, with leading coded as '1' and trailing/tie coded as '0'.

*Set difference.* This variable was used to indicate the difference between sets won by each player. Since this variable had only three gradations, we formed two binary variables. While the first binary variable contrasted situations where an absolute set difference between the players was 1 (e.g., 2-1) to where it was a tie, the second binary variable contrasted situations where the absolute set difference between the players was 2 (e.g., 2-0) to where it was a tie. In both variables, the set difference of 1 set (or 2 sets) was coded as '1' and a tie was coded as '0'.

*Interaction set difference x leading in sets.* For the variable set difference, only the absolute difference was taken into account, but not in whose favor the set difference was. For this reason, we computed the interaction between the two situational factors set difference and leading in sets. Because the results, upon using two dummy variables for the variable set difference, did not converge, the interaction effect was based on the continuous variable set difference.

*Point difference.* This variable was used to indicate the absolute difference between points won by each player within a set. The range of this variable was from 0 (in case of a tie) to the maximum of 10 (in case of a score of 10-0 or 0-10). This situational factor was coded as a continuous variable, with a higher number indicating that the point difference between the players was higher.

*Interaction point difference x leading in points.* Similar to the set difference, the point difference only took the absolute difference into account. For this reason, we formed an interaction term including the two situational factors point difference and leading in points.

*Consecutive points won.* This variable was used to indicate the number of points won in a row before the assessed point. A higher number of consecutive points won would indicate a higher controllability of the situation. The range of this variable was from 0 (in case it was the start of the set or the last point was lost) to a maximum of 10 (in case the score was 10-0). This situational factor was coded as a continuous variable, with a higher number indicating that more points were consecutively won by the players.

*Consecutive points lost.* This variable was used to indicate the numer of points lost in a row before the assessed point. In contrast to consecutive points won, a higher number of consecutive points lost would indicate a lower controllability of the situation. The range of this variable was from 0 (in case it was the start of the set or the last point was won) to a maximum of 10 (in case the score was 0-10). This situational factor was coded as a continuous variable, with a higher number indicating that more points were consecutively lost by the players.

#### *Interaction between importance of the situation and controllability of the situation*

Finally, we investigated the two interactions between remaining sets and leadings in sets as well as remaining points and leading in points in order to assess the interaction between the importance and the controllability of the situation.

*Interaction remaining sets x leading in sets.* This interaction allowed us to investigate whether the impact of the remaining sets on outward emotional reactions depended on whether the players were leading or not.

*Interaction remaining points x leading in points.* This interaction made it possible to investigate whether the impact of remaining points on outward emotional reactions depended on whether the players were leading or not.

### Consequences of Outward Emotional Reactions

#### *Outcome of next point*

Here, we investigated whether outward emotional reactions were linked to the performance in the subsequent point. We predicted the outcome of winning, with a won point coded as '1' and a lost point as '0'.

## Statistical Analysis

### Statistical Analysis for Antecedents of Outward Emotional Reactions

The coders identified no positive outward emotional reactions after losing a point and only five negative outward emotional reactions after winning a point. For this reason, we made two different computations. The first computation included only the won points and positive (vs. neutral) outward emotional reactions as binary outcome, and the second computation included only the lost points and negative (vs. neutral) outward emotional reactions as binary outcome. Since some of the players participated in more than one match and up to 117 points per match were observed for each player, outward emotional reactions and match characteristics were not independent of each other, but were nested within persons and within matches. In addition, we considered a temporal autocorrelation since consecutive outward emotional reactions closer in time expected to be more similar.

We used generalized linear models with a logit link (i.e., hierarchical logistic models) within the R package 'lme4' (Bates et al., 2015) to predict outward emotional reactions as binary outcomes. We modeled match and player as two independent random effects. To account for the possible temporal autocorrelation, we created lag variables for the outward emotional reactions. That is, the outward emotional reactions before the observed point (and thus the corresponding outward emotional reactions as a dependent variable) were coded as the variables 'lag 1', the outward emotional reactions before it as the variables 'lag 2', and so on. This took into account the likely autocorrelations in the outward emotional reactions, since the lme4 package does not have an option to include autocorrelation errors as a specific covariance structure. Specifically, we looked at the outward emotional reactions as well as the outcome of the point of up to five preceding points. For the outcome of the preceding points, the lag variables were coded as '1' when won or as '0' when lost. For the outward emotional reactions, negative ones were coded as '-1', positive ones as '1', and neutral ones as '0'. Due to technical problems with the camera or situations in which the players were outside of the camera view, outward emotional reactions could not be coded in 93 situations. These outward emotional reactions were treated as missing values, however, for the lag variables we coded them as '0' (neutral) to avoid a loss of cases.

To avoid convergence problems of more complex models, continuous predictors were grand mean centered, and the maximum number of iterations was increased. No issues with multicollinearity could be identified when looking at the generalized variance inflation factors of our models. Separately, for both positive and negative outward emotional reactions, we first calculated odds ratios for the bivariate relationships between each individual situational factor and the subsequent outward emotional reaction, adjusted only for the lag variables. In the final model, the significant interaction terms were included and the effects for each situational factor were adjusted by the effects of the other situational factors. The intraclass coefficient (ICC) was calculated for the empty model.

### Statistical Analysis for Consequences of Outward Emotional Reactions

In order to assess whether outward emotional reactions affect sports performance, we also composed two models. In the first model, we tested the effects of positive (vs. neutral) outward emotional reactions, and in the second model, we tested the effects of negative (vs. neutral) outward emotional reactions. In both cases, this was then linked to the outcome of the next point (won vs. lost). The first point of each set was not included in the analysis because there was no immediate preceding outward emotional reaction. Since outward emotional reactions could also influence performance over more than one point, lag variables were also explored. Again, we looked at the outward emotional reactions as well as the outcome of the point of up to five preceding points.

## RESULTS

## Descriptive Analysis of Codes

Overall, 1921 outward emotional reactions were recorded. In 93 situations (4.6%), players' outward emotional reactions could not be coded due to technical problems with the camera or situations in which the players were outside of the camera view. Of the remaining 1921 outward emotional reactions, the two coders agreed on 1781 of the ratings (92.71%). With regard to the 140 differently rated situations, only one of the coders identified a negative outward emotional reaction in 119 cases, and a positive outward emotional reaction in 21 cases, whereas the other coder rated all of the 140 outward emotional reactions as neutral. In the following analysis, these 140 outward emotional reactions were treated as neutral, so that only positive and negative outward emotional reactions were considered as such in the analysis if they were identified as such by both coders. In the analysis, 480 negative outward emotional reactions and 481 neutral outward emotional reactions were coded after having lost a point and 356 positive outward emotional reactions, 5 negative outward emotional reactions, and 599 neutral outward emotional reactions were coded after having won a point.

**TABLE 1 |** Antecedents of positive outward emotional reactions.

| Situational factor | Unadj. OR (95% CI) | Adj. OR (95% CI) |
|---|---|---|
| **Importance of the situation** | | |
| Stage of competition | 6.314* (1.134–35.133) | 14.965* (1.882–118.988) |
| Remaining sets[a] | 0.583* (0.470–0.724) | 0.782 (0.480–1.275) |
| Remaining points[a] | 0.946[§] (0.893–1.002) | 0.775* (0.713–0.843) |
| **Controllability of the situation** | | |
| Leading in sets | 3.009* (1.882–4.811) | 1.439 (0.684–3.030) |
| Leading in points | 1.056 (0.705–1.582) | 1.049 (0.546–2.015) |
| Set difference (1 vs. 0) | 2.026* (1.359–3.019) | 1.045 (0.494–2.212) |
| Set difference (2 vs. 0) | 2.434* (1.882–4.811) | 0.504 (0.157–1.621) |
| Set difference x leading in sets[b] | | 1.520 (0.419–2.771) |
| Point difference[a] | 0.753* (0.641–0.864) | 0.503* (0.404–0.626) |
| Point difference x leading in points | | 1.334* (1.016–1.752) |
| Consecutive points won[a] | 0.865 (0.715–1.046) | 0.810[§] (0.636–1.033) |
| Consecutive points lost[a] | 0.872 (0.728–1.044) | 0.872 (0.688–1.105) |
| **Interaction between importance of the situation and controllability of the situation** | | |
| Remaining sets x leading in sets | | 0.295* (0.141–0.617) |
| Remaining points x leading in points[b] | | 0.960 (0.839–1.098) |

*[§]$p \leq 0.10$; *$p \leq 0.05$; [a]Grand mean centered; [b]This interaction was not considered in the final model.*

## Antecedents of Positive Outward Emotional Reactions After Winning a Point

For the prediction of positive outward emotional reactions, none of the lag variables for preceding outcomes of the point were significant and, therefore, no lagged effects for the outcome of the point were included in the models. Since the three preceding outward emotional reactions were significantly related to the current outward emotional reactions, all following models were adjusted for these lagged effects. A model including only these three lagged effects of outward emotional reactions had a deviance value of 843.34, compared to 882.45 for the intercept only (empty) model ($\chi^2(3) = 39.11$, $p < 0.05$). The intraclass correlation (ICC) for person was 0.294, and for match was 0.367. The results for the individual situational factors are presented in **Table 1**, including odds ratio for the bivariate relationships and odds ratio adjusted by all situational factors and significant interactions.

### Situational Factors for Importance of the Situation

For the bivariate relationships, the two situational factors stage of competition (*OR* = 6.314, *CI* = 1.134–35.133) and remaining sets (*OR* = 0.583, *CI* = 0.470–0.742) were significant predictors of positive outward emotional reactions. In addition, the situational factor remaining points approached significance (*OR* = 0.946, *CI* = 0.893–1.002). In the final model, the two situational factors stage of competition (*OR* = 14.695, *CI* = 1.882–118.988) and remaining points (*OR* = 0.775, *CI* = 0.713–0.843) were significant predictors of positive outward emotional reactions. Thus, after having controlled for all situational factors, the results showed that after winning a point, the players were more than fourteen times more likely to show positive outward emotional reactions in elimination matches than in group stage matches. However, there was a large confidence interval. Furthermore, the likelihood of positive outward emotional reactions decreased by about 22.5% for each point further away from the potential end of the set.

### Situational Factors for Controllability of the Situation

For the bivariate relationships, the four situational factors, leading in sets (*OR* = 3.009, *CI* = 1.882–4.811), set difference of one set (*OR* = 2.026, *CI* = 1.359–3.019), set difference of two sets (*OR* = 2.434, *CI* = 1.882–4.811), and point difference (*OR* = 0.753, *CI* = 0.641–0.864), were significant predictors of outward emotional reactions. In the final model, only the situational factor point difference (*OR* = 0.503, *CI* = 0.404–0.626) was a significant predictor of positive outward emotional reactions. Thus, after controlling for all situational factors, after winning a point the chance of a positive outward emotional reaction decreased by about 49.7% when the point difference increased by one point. In addition, the interaction between the two situational factors point difference and leading in points was a significant predictor (*OR* = 1.334, *CI* = 1.016–1.752). When the players were leading, the OR of point difference was 0.671, while when the players were trailing or tied, the OR of point difference was reduced to 0.503. This means that the effect of point difference on positive outward emotional reactions was moderated by leading in points. The effect was stronger when the players were trailing or tied. Finally, the effect for the situational factor consecutive points won approached significance (*OR* = 0.810, *CI* = 0.636–1.033). This suggests that the chance of positive outward emotional reactions decreased by about 19% when the number of consecutive points won increased by one point.

### Situational Factors for Interaction Between Importance/Controllability of the Situation

The interaction of the two situational factors, remaining sets and leading in sets, was a significant predictor of positive outward emotional reactions (*OR* = 0.295, *CI* = 0.141–0.617). Specifically, when the players were leading, the OR for remaining sets was 0.231 and when the players were trailing or tied, the OR for remaining sets was 0.782. Thus, the results indicate that in situations with more remaining sets the chance of positive outward emotional reactions was more reduced when the players were leading compared to when they were trailing or tied.

## Antecedents of Negative Outward Emotional Reactions After Losing a Point

For the prediction of negative outward emotional reactions, again, none of the lag variables for the preceding outcomes of the point showed a significant effect, but we found significant effects up to the third lag variable for the preceding outward emotional reactions. A model including lagged effects for three preceding outward emotional reactions had a deviance value of 1249.40, compared to 1258.30 for the intercept only (empty) model ($\chi^2(3) = 8.983$, $p < 0.05$). We therefore included three lag variables, as in the models for positive outward emotional reactions. The intraclass correlation (ICC) for person was 0.036 and for match 0.021 in the intercept only (empty) model. Due to the low number of five negative outward emotional reactions after winning a point, they were not considered in this analysis. The results for the individual situational factors are presented in **Table 2**, including odds ratio for the bivariate relationships and odds ratio adjusted by all situational factors and significant interactions.

**TABLE 2** | Antecedents of negative outward emotional reactions.

| Situational factors | Unadj. OR (95% CI) | Adj. OR (95% CI) |
|---|---|---|
| **Importance of the situation** | | |
| Stage of competition | 0.853 (0.545–1.335) | 0.809 (0.504–1.299) |
| Remaining sets[a] | 0.737* (0.628–0.865) | 0.720[$] (0.496–1.045) |
| Remaining points[a] | 0.965 (0.923–1.008) | 0.913* (0.862–0.968) |
| **Controllability of the situation** | | |
| Leading in sets | 1.038 (0.742–1.452) | 0.947 (0.590–1.520) |
| Leading in points | 1.053 (0.777 –1.429) | 1.158 (0.819–1.637) |
| Set difference (1 vs. 0) | 1.502* (1.111–2.031) | 1.100 (0.623–1.942) |
| Set difference (2 vs. 0) | 1.918* (1.286–2.861) | 1.319 (0.577–3.016) |
| Set difference x leading in sets[b] | | 0.658 (0.344–1.257) |
| Point difference[a] | 0.936[$] (0.868–1.009) | 0.831* (0.747–0.925) |
| Point difference x leading in points[b] | | 0.938 (0.788–1.116) |
| Consecutive points won[a] | 1.098 (0.963–1.251) | 1.115 (0.956–1.300) |
| Consecutive points lost[a] | 0.981 (0.867–1.110) | 1.032 (0.893–1.193) |
| **Interaction between importance of the situation and controllability of the situation** | | |
| Remaining sets x leading in sets | | 1.924* (1.117–3.313) |
| Remaining points x leading in points[b] | | 1.020 (0.924–1.127) |

*[$]$p \leq 0.10$; *$p \leq 0.05$; [a]Grand mean centered; [b]This interaction was not considered in the final model.*

### Situational Factors for Importance of the Situation

For the bivariate relationships, the situational factor remaining sets was a significant predictor (*OR* = 0.737, *CI* = 0.628–0.865). In the final model, the situational factor remaining points was significant (*OR* = 0.913, *CI* = 0.862–0.968) and the situational factor remaining sets approached significance (*OR* = 0.720, *CI* = 0.496–1.045). Thus, after having controlled for all situational factors, the chance of negative outward emotional reactions decreased by about 8.7% for each point further away from the potential end of the set, and by about 28% for each set further away from the potential end of the match.

### Situational Factors for Controllability of the Situation

For the bivariate relationships, the two situational factors set difference of one set (*OR* = 1.502, *CI* = 1.111–2.031), and the set difference of two sets (*OR* = 1.918, *CI* = 1.286–2.861) had significant effects. Furthermore, the situational factor point difference approached significance (*OR* = 0.936, *CI* = 0.868–1.009). In the final model, only the situational factor point difference was significant (*OR* = 0.831, *CI* = 0.747–0.925). This result suggests, after having controlled for all situational factors, that the chance of negative outward emotional reactions decreased by about 16.9% when the point difference increased by one point.

### Situational Factors for Interaction Between Importance/Controllability of the Situation

The interaction of the two situational factors, remaining sets and leading in sets, was a significant predictor for negative outward emotional reactions (*OR* = 1.924, *CI* = 1.117–3.313). Specifically, when the players were leading, the OR for remaining sets was 1.385 and when the players were trailing or tied, the OR for remaining sets was 0.720. Thus, the results showed that in situations with more remaining sets the chance of negative outward emotional reactions was increased when the players were leading. On the contrary, when the players were trailing or tied the chance of negative outward emotional reactions was decreased with more remaining sets.

## Consequences of Outward Emotional Reactions

Finally, we conducted analyses to assess whether positive or negative outward emotional reactions can significantly predict the outcome of the next point. A total of 1813 observed points were included in this analysis. Thus, points where the immediately preceding outward emotional reactions were missing were not considered. This included those points where preceding outward emotional reactions could not be coded due to technical problems (*n* = 93) as well as the first point of each set (*n* = 108). Neither the lag variables for preceding outcomes of the point nor outward emotional reactions were significant and therefore no lagged effects were included in the models. No significant effects were found for both positive outward emotional reactions (*OR* = 0.954, *CI* = 0.734–1.239) and negative outward emotional reactions (*OR* = 1.117, *CI* = 0.892–1.399). Thus, the results suggest that neither positive nor negative outward emotional reactions could predict the outcome of the following point.

# DISCUSSION

This study aimed to examine antecedents and consequences of outward emotional reactions during competitive table tennis matches. The results showed positive outward emotional reactions were more likely in elimination matches. Both positive and negative outward emotional reactions were less likely when there were more remaining points until the potential end of the set and also when there was a higher point difference between the players. For positive outward emotional reactions, the effect of point difference was stronger in situations where the players were trailing or tied than in situations where the players were leading. In addition, with more remaining sets until the potential end of the set, the chance of positive outward emotional reactions was more reduced when the players were leading compared to when they were trailing or tied. For negative outward emotional reactions, with more remaining sets until the potential end of the match, they were more likely when the players were leading in sets, but less likely when they were trailing or tied in sets. Finally, we found that neither positive nor negative outward emotional reactions could predict the outcome of the next point.

## Antecedents of Outward Emotional Reactions

Situations that are appraised as relevant for the individual's goal realization have a greater influence on emotional responses (Lazarus, 1991; Scherer, 2013). It is therefore consistent with our hypothesis that situational factors representing the importance of a situation increased the likelihood of both positive and negative outward emotional reactions. The controllability of the situation is particularly relevant in the emotion generation process for stimuli that are not congruent with the current goal (Scherer, 2013). Thus, we hypothesized that the controllability of the situation would reduce the likelihood of negative outward emotional reactions, but would not influence positive outward emotional reactions. However, in contrast to this hypothesis, the results show that, after having controlled for all situational factors, none of the situational factors representing the controllability of the situation could predict the likelihood of negative outward emotional reactions; some of them, however, could predict the likelihood of positive outward emotional reactions. Below, we will first discuss the findings of the individual situational factors concerning the importance of the situation, then the factors related to the controllability of the situation, and finally the interaction of factors related to the importance and controllability of the situation.

### Importance of the Situation

In accordance with our hypothesis, the results show that positive outward emotional reactions were more likely in elimination matches than in group stage matches. These findings are in line with a study with handball players (Moesch et al., 2015). Since a defeat in an elimination match cannot be compensated for in future matches, the outcome of a won point is more important. This makes the situation more likely to elicit emotions (Scherer, 2013). One possible explanation for the finding that the stage of competition does not influence the likelihood of negative outward emotional reactions is the concept of loss aversion, indicating that the fear of losing is associated with stronger emotional reactions than the hope of a possible win (Tversky and Kahneman, 1991). Irrespective of the stage of competition, there is a general tendency to react emotionally after losing a point, which may also explain why overall more negative than positive outward emotional reactions were identified in this study.

A confounding effect was found for the situational factor remaining sets for positive outward emotional reactions. While the effect was significant in the bivariate model, its significant interaction with the situational factor leading in sets may explain why it was not significant in the final model (this interaction effect will be discussed later). The results were less conclusive for negative outward emotional reactions. Although the effect only approached significance, a comparison of the statistical parameters showed a stronger effect in the final model, indicating that negative outward emotional reactions are more likely in sets closer to the end of the match. The outcome of a set closer to the end of a match can be decisive for the final result of the match, thus making the situation more important than the outcome of a set at the beginning of a match. In relation to the situational factor remaining points, its effect was significant in the final model, but not in the model with bivariate relationships, for both positive and negative outward emotional reactions. One can speculate that other situational factors in the regression model suppressed irrelevant parts of the variance in the variable remaining points. In addition, that more conclusive effects were revealed at the point level compared to the set level, is consistent with the observation that players often “reset” their mind after the end of a set (Lewis et al., 2017).

### Controllability of the Situation

Similar to the importance of the situation, we found some confounding effects for situational factors with regards to the controllability of the situation. More specifically, the situational factors set differences (for a set difference of both one or two sets) were significant in the model with the bivariate relationships, but not in the final model, for both positive and negative outward emotional reactions. The same was found for the situational factor leading in sets, but only for positive outward emotional reactions. Thus, we assume that the effect of these situational factors overlaps with the effect of other situational factors. In contrast to our hypothesis, after having controlled for all other situational factors, none of the situational factors representing the controllability of the situation showed an effect on negative outward emotional reactions. This is surprising as the controllability is regarded as an important factor in the emotion generation process, especially for stimuli that are opposing the current goals (Scherer, 2013). Since appraisal processes related to the controllability of the situation come into play at a later stage in the emotion generation process (Scherer, 2013), this indicates a stronger impact of emotion regulation strategies. Since negative emotions are more difficult to regulate than positive ones (Martinent et al., 2015), this again could underline the potential role of loss aversion, which suggests that the effects of negative events are less dependent on situational factors (Tversky and Kahneman, 1991).

The point difference was the only situational factor that predicted both positive and negative outward emotional reactions in the final model. The smaller the point difference between the players was, the more likely an outward emotional reaction occurred. This is interesting because the point difference differently represents the controllability of the situation, depending on whether the player is leading or not. It could be that, regardless of who is leading, the predictability of the situation is one important facet in the appraisal process in sports competitions (Thatcher and Day, 2008). Thus, in times of a tight point score it is difficult to predict who will win the set, which generally increases the emotionality of the situation. Contrary to our hypothesis, it could further be shown that the situational factor leading in points moderated the effect of the point difference on positive outward emotional reactions. In both situations, players were more inclined to show positive outward emotional reactions when there was a small point difference. However, in times of a small point difference, the likelihood was higher when the players were trailing or tied than when the players were leading. In line with the observation that leading in matches is often associated with feelings of confidence and relaxation (Lewis et al., 2017), this can make the situation less emotional and therefore reduces the likelihood of positive outward emotional reactions. This may also explain the trend that positive outward emotional reactions became more and more unlikely when players were winning points consecutively.

### Interaction of Importance of the Situation and Controllability of the Situation

We further assessed the interaction between the importance of the situation and the controllability of the situation. For negative outward emotional reactions, the results suggest that players who were leading in sets were less likely to show negative outward emotional reactions when there were less remaining sets until the potential end of the match. This is in line with our hypothesis that the controllability of the situation can counteract the effects of the importance of the situation. If players were leading in the final phase of the match, this can give them a sense of confidence and control (Lewis et al., 2017), which in turn reduces the likelihood of negative outward emotional reactions. In contrast, if players are trailing or tied in the final phase of the match, the effect of the lower controllability of the situation and the higher importance of the situation can reinforce each other. This may account for the increased probability of negative outward emotional reactions in such situations found in our study. Contrary to our hypothesis, the findings also revealed an interaction effect for positive outward emotional reactions. More specifically, it was shown that positive outward emotional reactions were more likely to occur in the final phase of the match when they were leading. Disengagement processes may explain why this effect was not as strong in the final phase of the match when the players were trailing or tied (Gaudreau et al., 2005).

## Consequences of Outward Emotional Reactions

We further explored whether outward emotional reactions can influence sports performance. Our study design allowed us to use the next point as an objective performance indicator that closely follows the emotion (Uphill et al., 2014). The results indicate that neither positive nor negative outward emotional reactions have an impact on the outcome of the next point. Although other studies that focused on overt verbalizations and gestures in tennis reported debilitative effects of negative and facilitative effects of positive outward emotional reactions (e.g., Zourbanos et al., 2015), our results are in line with studies that did not report an effect on performance (e.g., Van Raalte et al., 2000). The inconsistency of these findings demonstrates that predicting sports performance in general is a difficult task (Nevill et al., 2008), which could be supported by considering additional situational and personal variables (e.g., Moesch et al., 2018). Since emotions can have a stronger effect on observers when they are identifiable from the outside, the study of outward emotional reactions seems particularly suitable for understanding the interpersonal consequences of emotions, an area that has received scant attention in sport psychology (Tamminen and Bennett, 2017). There are several laboratory studies within the context of sport that indicate how outward emotional reactions can influence the opponents' cognitions, emotions, and behaviors (e.g., Furley and Schweizer, 2014; Furley et al., 2015); however, research in the field is lacking. Given the importance of increasing the ecological validity of studies that focus on the relationship between emotions and sports performance (Uphill et al., 2014), we are convinced that with the increased use of innovative research methods (e.g., automatic recognition of body signals; Hetland et al., 2018), the explicit focus on outward emotional reactions can contribute to further insights in this area.

## Implications for Practice

The present results have various implications for applied work, which are worth examining in future studies. Although our results did not indicate a direct influence of outward emotional reactions on performance, it can be argued that there are situations in which players would benefit from emotion regulation strategies that prevent the occurrence of outward emotional reactions (Lane et al., 2012). Since our study suggests that in certain situations there is an increased likelihood of both positive and negative outward emotional reactions, it seems promising to tailor the use of sport psychological techniques to psychological demands of such situations (Martinent et al., 2015). Here, reflexive self-talk interventions could raise awareness of the players' organic self-talk in such situations, which would possibly help to address potential irrational performance beliefs and subsequent outward emotional reactions (Latinjak et al., 2019). Furthermore, relaxation strategies (e.g., systematic breathing; progressive muscle relaxation) can help to deal with increased arousal in situations that are associated with a higher likelihood of outward emotional reactions (Pineschi and Di Pietro, 2013).

## Limitations and Future Directions

One limitation of the current study is the exclusive use of observational data. Although this methodology made it possible to study emotions 'online' in a real sports competition, an emotion is typically defined as having a subjective experience and physiological processes in addition to the behavioral component (Mauss and Robinson, 2009). In particular, the subjective experience is often considered the most essential component that distinguishes an emotion from other psychological states (Scherer, 2009). Nevertheless, outward emotional reactions imply consequences, especially with regards to the interpersonal side of emotions (e.g., Furley et al., 2015), which can hardly be explained by the subjective experience. For this reason, it seems that especially the combination of the different emotion components can contribute to a better understanding of the role of emotions in sports. In line with emotion theories (Lazarus, 1991; Scherer, 2013), importance and controllability were considered as potential moderators of outward emotional reactions and contributed to our understanding of the antecedents of emotions in sports competitions. Nevertheless, it is worth noting that these were operationalized based on objective criteria. For a better understanding of their role, future research could potentially explore their relevance for emotions through subjective measures focusing on individuals' appraisal processes (e.g., Sève et al., 2007; Lewis et al., 2017).

Although the statistical analysis took the multi-level structure of the data into account, we did not explicitly deal with inter-individual differences. In sports competitions, however, it can often be seen that players differ in their tendency to show outward emotional reactions. As research points to individual dispositions influencing appraisal processes (Scherer, 2009), inter-individual differences could be another interesting line of future research. Moreover, in the current study we contrasted situations where players were leading with situations where players were not leading (i.e., for statistical reasons described in the methods section, trailing and tie was combined into one category). Because trailing or tied situations are qualitatively different from each other, future studies could consider this distinction. In addition, we only focused on whether or not positive/negative outward emotional reactions occurred, but we did not consider their intensity. It seems plausible that specifically outward emotional reactions with a high intensity (e.g., players make a fist and give a loud shout) have an effect on the opponent. Similar to the emotion experience (Hanin, 2007), a research design that takes their intensity into consideration could thus be specifically relevant with regard to sports performance. Finally, advances in technology appear to offer fascinating perspectives for future lines of research (e.g., Hetland et al., 2018). The automatic coding of physical features signaling outward emotional reactions could allow to draw on huge amounts of data in real sports competitions and thus help us to understand the role of emotions in sports.

# CONCLUSION

In conclusion, the present study employed a novel methodological perspective to investigate the role of emotions in table tennis. The findings provide valuable preliminary evidence of how various situational factors related to the importance and controllability of the situation influence the likelihood of positive and negative outward emotional reactions. This knowledge is useful both from a theoretical as well as a practical perspective to understand why players can react so differently to similar situations, such as winning or losing a point. Furthermore, our study underlines the importance of considering all emotion components, which, with the progress of new technologies, can help to unveil new insights into the relationship between emotions and sports performance.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by ethics committee of the University of Thessaly Department of Physical Education and Sport Sciences. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

JF wrote the manuscript. JF, DJ, AH, and A-ME conceptualized the study. JF and DZ organized the data collection. EF conducted the statistical calculations. DJ, AH, A-ME, and EF helped to edit the manuscript. All authors approved the final version of the submitted manuscript.

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# (How) Does Affect Influence the Formation of Habits in Exercise?

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**Objectives:** Habitually instigated exercise is thought to increase health behavior maintenance. Previous research has explored several aspects of habit formation. However, there is a lack of longitudinal research investigating affective determinants, especially post-exercise affective states. Therefore, the present study aimed to investigate (a) if behavior frequency will enhance automaticity, (b) if positive affect will enhance automaticity, and (c) if positive affect will moderate the relationship between behavior frequency and automaticity.

**Methods:** 226 participants (64% females, mean age 24 years) who attended weekly sports and gym classes at two universities were followed for 13 weeks. Class attendance was documented on a weekly basis (behavior frequency) during the semester. Before, during and immediately after each class, participants filled in the Feeling Scale (affective valence). Furthermore, at the beginning of each class, they answered a question about their automaticity in arriving at the decision to attend the class (instigation habit). We used a two-level modeling approach to predict subsequent automaticity by the different constructs at the previous attendance.

**Results:** The cumulative frequency of prior class attendance did not significantly enhance the automaticity of the decision to re-attend the class. There were significant effects of valence on automaticity on the between-subject level, i.e., a one-point higher mean valence score was associated with a 0.62 point increase in automaticity ($p = 0.001$). No moderation effects of affect on the association between behavior frequency and automaticity were observed.

**Conclusion:** Behavior repetition, albeit not significant, and positive affective states at the end of an exercise class may be beneficial in building exercise instigation habits. Practitioners and researchers alike may thus want to emphasize the importance of behavior repetition and affective response for health behavior maintenance.

**Keywords: physical activity, exercise, behavior change, behavior maintenance, habit formation, automaticity, affect**



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## INTRODUCTION

"The first letter of the psychological alphabet is A for Attitude."—This statement by Jung, quoted by Hamilton (1929, p. 126), puts the cognitivist paradigm, which later dominated psychological research, in a nutshell. However, since authors like Ekkekakis and Zenko (2016) propose the "escape from cognitivism," one might consider that A stands for Affect. In the context of physical activity

(PA), affect plays a key role and increasingly gains attention among researchers and practitioners alike. On the one hand, affect serves as a motivator of behavior (Finucane et al., 2003) and is involved in the process of PA behavior maintenance (Rhodes and Kates, 2015), and on the other hand, PA can influence affect in both negative (Ekkekakis et al., 2008) and positive (Ekkekakis et al., 2000; Hogan et al., 2013) ways. This study focuses on the role of affective states in the formation of habitual instigation of exercise. Affective states subsume the whole range of states based on core affect (Scherer, 1984; Ekkekakis, 2003), which is defined as "the most elementary consciously accessible affective feelings (and their neurophysiological counterparts) that need not be directed at anything" (Russell and Barrett, 1999, p. 806). Thus, these rapidly and automatically occurring feeling states (Slovic et al., 2007), with the two dimensions valence (pleasure/displeasure) and arousal (low/high) (Russell, 1980), differ from emotions (Ekkekakis, 2003). The broader and general term "affect" refers to any other valenced responses in the global domain of affective feelings (Ortony et al., 1987).

In addition to a potential positive impact on affect, several other benefits of PA with regard to psychological variables have been reported. For example, there is evidence that regular PA reduces levels of stress and anxiety as well as incidence rates of depression, and improves overall psychological well-being (Goodwin, 2003; Ströhle, 2009; Rebar et al., 2015; Rhodes et al., 2017). Furthermore, current research demonstrates that regular PA is associated with the prevention of over 25 chronic medical conditions (Warburton et al., 2007; Garber et al., 2011). Nevertheless, about 31% of adults worldwide are physically inactive (Hallal et al., 2012) and only an alarming 22.6% of adults in Germany meet the WHO recommendations for aerobic and muscle strengthening PA (Finger et al., 2017), even though many individuals may have the intention to be physically active. For example, a recent study showed that 90% of participants intended to engage in moderate PA for at least 150 min per week (de Bruijn et al., 2009). This failure to translate intentions into behavior is a phenomenon referred to as intention-behavior-gap, which reflects "the black-box nature of the underlying psychological process that leads from intention to action" (Sniehotta et al., 2005, pp. 143–144). In their meta-analysis, Rhodes and de Bruijn (2013) quantified the intention-behavior-gap by showing that only 42% of "intenders" acted on their PA intentions. Also, interventions that focus on enhancing intentions thereby promoting behavior change have limited success (Webb and Sheeran, 2006; Rhodes and Dickau, 2012). Thus, there is not only an urgent need to make more people cognitively aware of the health benefits of sustained PA, but to also help them to successfully carry out an intended behavior, such as engaging in PA. Focusing on intention as the proximal determinant of behavior, as postulated in traditional social-cognitive models like the Theory of Planned Behavior (TPB; Ajzen, 1985), may not be sufficient in explaining actual behavioral instigation and regular execution. Rather, automatic processes need to be additionally considered (de Bruijn and Rhodes, 2011). The two pathways are summarized in dual process theories such as the Affective-Reflective Theory (ART) of physical inactivity and exercise. The ART was developed by Brand and Ekkekakis (2018) to explain the initiation of exercise-related actions or the persistence of physical inactivity. According to the theory, a fast type-1 process leads to an action impulse via automatic associations and automatic affective valuations (Antoniewicz and Brand, 2016), and a slower type-2 process can result in action plans via reflective evaluation provided that self-control resources are available (Baumeister and Heatherton, 1996). Explaining their PAAM model that identifies predictors of PA adoption and maintenance, Strobach et al. (2020) argue that the control of behavior gradually shifts from being explicitly to being implicitly controlled when it is repeated under stable contexts due to habit formation. One study found that past exercise behavior had a significant positive effect on the intention to continue exercising during the next 6 months, thus stabilizing it, while at the same time past behavior did not exhibit a significant indirect effect via intention on future behavior, but had a strong direct effect (Rodrigues et al., 2019). In sum, one of the implicit constructs that should be considered with regard to the intention-behavior-gap is habit (de Bruijn and Rhodes, 2011).

Gardner and Lally (2018, p. 207) define habit as "a process whereby encountering a cue triggers an impulse to perform an action that has, through learning, become a learned response to the cue." In order to develop a method of measuring habit, Verplanken and Orbell (2003) summarize the basis features of habit as follows: previous repetition of the behavior; and features of automaticity, namely difficulty of overruling strong habits, lack of awareness, efficiency; and their reflection of someone's identity. Thus, automaticity is a main characteristic of habit (Aarts and Dijksterhuis, 2000; Hagger, 2019). Assuming that habit automaticity is cue-dependent (Orbell and Verplanken, 2010; Wood and Rünger, 2016), once behavior has become habitual it is supposed to be insensitive to lack of motivation (Rebar et al., 2019; Gardner et al., 2020). In their recent meta-analysis, Gardner et al. (2011) found a medium-to-large correlation between habit and behavior, suggesting that habit explains for about 20% of variance in those health-related behaviors. Combining these two effects of habit on behavior, namely bridging dips in motivation and a correlation between habit strength and behavior frequency (Gardner et al., 2012; Rebar et al., 2016), it is possible that establishing habits might facilitate behavior maintenance. The underlying assumption is that the habit process may trigger selecting an action out of several behavioral alternatives. This habitual selection of an action for performance is defined as habitual instigation (in contrast to habitual execution, which means habitually performing the already chosen behavior) (Gardner et al., 2020). In a randomized controlled trial examining the effect of a workshop on establishing a preparatory exercise habit, the experimental group indeed showed a significant increase in physical activity, use of cues and practice consistency compared to the control group (Kaushal et al., 2017).

Theoretically, habits are easily developed, as repetition of behaviors in stable contexts might be sufficient to strengthen links between salient cues and subsequent actions in associative memory, which may in turn result in highly accessible context-behavior associations that speed up enactment (Verplanken, 2006; Danner et al., 2008; Gardner and Lally, 2018; Hagger, 2019). However, reality is more complex. In their attempt to model habit formation in the real world, Lally et al. (2010)

asked volunteers to repeat a self-chosen health behavior in the presence of a cue of their choice and to report automaticity on a daily basis. An asymptotic curve reflected the process of habit formation, assuming that automaticity increases rapidly with every repetition in the first days while additional gains then decelerate over time. Finally, habit formation reaches a point where growth in automaticity is no longer possible despite maintaining repetitions. This model was valid for 62 of the 82 participants, which indicates that repetition of behavior was sufficient to form automaticity in these 62 individuals. However, there was variation in the absolute level of achieved automaticity and the number of days needed to reach this individual maximum. Thus, rates of automaticity formation are highly variable albeit an equal number of repetitions, leading the authors to conclude that the final habit strength is not exclusively determined by repetition. While it is possible that anticipated affect or intrinsic rewards played a role in the participant's choice of the health behavior, the study reveals no information about affect itself. In the present study, the research question was whether affective states is another variable that influences habit formation.

Conceptually, determinants of habit formation can be categorized into variables influencing the intention to act, the likelihood of acting on intentions, the motivation to maintain a behavior after successfully initiating it, or the development of cue-action associations (Gardner and Lally, 2018). As for affect, this intrinsic rewarding outcome is supposed to play a role on multiple levels: First, it may lead to more frequently performed behavior and sustained motivation which in turn may prompt maintenance and habit development. This assumption is based on a psychological hedonism of the past which is associated with learning theories (Insko and Schopler, 1972). An example is the "law of effect," which was developed by Thorndike (1911). His animal-learning studies led him to conclude that a behavioral response to a cue will be more likely to be shown after encountering the stimulus again in the future, if the behavior was followed by satisfaction. Hedonism of the past, in general, states that individuals engage in behavior that maximized reward and minimized displeasure in the past (Insko and Schopler, 1972). In fact, individuals having a more positive affective response during acute moderate-intensity exercise were more active in the future (Schneider et al., 2009). Second, affect may increase or expedite context-behavior associations. This assumption is based on a premise resulting from a combination of hedonism of the past and a stimulus-response approach: When the affective response to a cue-response situation is pleasurable, a learned association between stimulus and response will be formed (Insko and Schopler, 1972). In the law of effect, a positive correlation between satisfaction and the resulting strengthening of the bond is assumed (Thorndike, 1911). In line with this, the Associative Cybernetic Model proposes that once an outcome is rewarding, the signal to habit memory, which strengthens the stimulus-response relationship, will be supported (de Wit and Dickinson, 2009). Consequently, this process reinforces the contribution of each rewarded behavior performance to habit formation (Wiedemann et al., 2014) and can therefore explain different curves of habit formation despite comparable behavioral frequency. Thus, affect—especially during exercise—is supposed to influence habit development not only due to repetition of the behavior but also via the reinforcement of the relationship between behavioral repetition and habit strength.

Investigating determinants of habit strength, one cross-sectional study found an interaction between motivational regulation and past behavior (Gardner and Lally, 2013). The authors hypothesized that past behavior may be a stronger predictor of habit strength among intrinsically motivated participants, suggesting that enjoyment derived from autonomously motivated PA may strengthen the relationship between past behavior and habit development even more. In line with this, another study investigated intrinsic rewards such as enjoyment and found that intrinsic rewards predict exercise frequency via habit strengths for maintainers (and via behavioral intentions for initiators) (Phillips et al., 2016). Furthermore, Kaushal and Rhodes (2015) investigated the influence of affective judgments about exercise on habit formation in a longitudinal study among new gym members, and reported that affective judgments at baseline were the main predictor of habit development. The authors concluded that a reward like positive affect increased the likelihood of an individual performing the behavior again without conscious deliberation. However, the study had several limitations, i.e., the first follow-up assessment of habit scores was done after 6 weeks; and, in particular, affective judgments refer to beliefs or expectations about affect and are therefore not affective responses *per se* (Ekkekakis et al., 2018). Overall, only few long-term studies that examined affective determinants of habit formation are available, especially in the context of physical exercise. Therefore, the purpose of the present longitudinal study was to examine the role of affective states and behavior repetition in the formation of real-world exercise instigation habits among adults. Since it is recommended in the literature to not only analyze affective changes in group means, but also at an individual level, we explored affective states on both between-person and within-person level (Ekkekakis, 2008). We hypothesized that (a) behavior frequency will enhance automaticity, (b) positive affect will enhance automaticity, and (c) positive affect will moderate the relationship between behavior frequency and automaticity (see **Figure 1**).

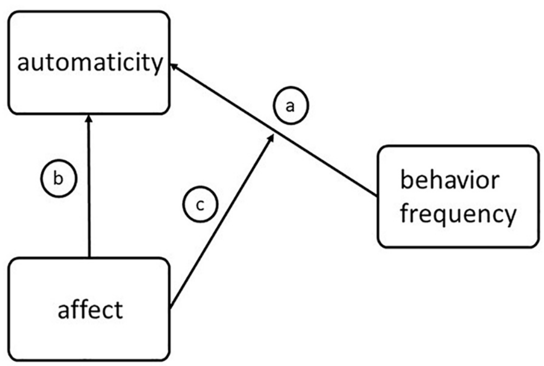


**FIGURE 1 |** Hypotheses.

# MATERIALS AND METHODS

## Participants

Participants were university students or employees who participated in 10 sports and gym classes at no or low cost during the winter term 2015/16. These courses are unconditionally offered each term to all students or employees of the universities. As the limited available spots were assigned by applying the "first come first served" principle, interested persons had to register for specific courses ahead of time. Each specific class started at the beginning of the lecture period and there was a great variability in date, coach and participants from semester to semester. Given this fluctuation, the participants may have attended a similar course, but they cannot have attended the identical course on the same date, with the same instructor, the same co-participants nor at the same sports facilities as before. Therefore, context-specific cues that may have been associated with the exercise behavior before change. We consequently assume that participants started the class with no habit to attend this specific class and are appropriate for studying the development of a new habit. We included classes with a medium size (about 15–30 participants) and an adequate practice time (about 60–90 min). Thus, our study sample can be regarded as a convenience sample, although participants were not self-selected as throughout the courses nearly all consented to participate in our study. This approach led to a total sample of 145 female und 81 male ($N$ = 226) university students and employees, who provided sufficient complete data and were included in the presented analyses. Course instructors of the 10 classes were informed prior to the study about the design and aims, and all instructors gave their consent to participate in this research. Study participation for participants of the sports classes was voluntary and interested individuals were asked to provide written informed consent, which was done by nearly all of potential participants. However, we have no information on the number of individuals who refused to participate, as the complete list of participants attending the sports classes was not available to our research team due to data protection policies. The study was approved by the Data Security Commissioner and the Ethics Committee of one of the universities.

## Design and Setting

In order to study the influence of affective states and behavior frequency on automaticity formation on a between- and within-person level, this study had a longitudinal design with weekly measurement time points. It was conducted at two German universities during the winter semester 2015/2016 (October 2015 to February 2016). Course duration varied slightly depending on the length of the semester at each university (ranged from 13 to 15 sessions; for comparability, only the first 13 weeks were included in the analyses), and no classes took place during the 2-weeks Christmas holiday break. The number of weeks needed to form a habit is highly variable (for an overview see Hagger, 2019), but since evidence suggests that attendance in the first 5 weeks is crucial for habit formation (Armitage, 2005), we consider the time span of one term to be sufficient. The study settings were sports and gym classes during which participants carried out various types of aerobic exercise, including dance-related exercise (Zumba, Bokwa), martial arts (Kickboxing, Taekwondo, Capoeira), Freeletics (a specific set of endurance and strength exercises), and basketball training.

## Procedure

Individuals who agreed to participate in the study signed a consent form during their first attendance of the course. Participants then completed a baseline questionnaire to report past exercise behaviors and habit strength (please refer to section "Baseline Questionnaire"). Student assistants attended all selected courses on a weekly basis. At the beginning of a course, they documented participation and handed out a short questionnaire measuring affective states and automaticity to all attending study participants. After approximately half of the class time (after about 45 min), and immediately after the training, the same short questionnaire was again provided to participants. After each class, the student assistants regathered all questionnaires. In order to collect the data pseudonymously, each participant had an individual code, consisting of letters and numbers derived from family names, year and place of birth. This enabled the lead investigator to match the questionnaires to each participant.

## Measures

Participants filled in a baseline-questionnaire during their first week of attendance and, every week they attended the class, a short weekly questionnaire at three time points: at the beginning of the training, approximately after half of the class time, and immediately afterward. In the following, only measures relevant for the present analyses are described.

### Baseline Questionnaire

#### *Sociodemographic Information*

Sex (male, female), age (in years), and student status (student yes/no) were collected.

#### *Past Exercise Behavior*

To adjust for past behavior, participants were asked whether they had already been exercising on a regular basis (yes/no) before registering for the class. If they responded with "yes," they were asked to provide information on how long they had been exercising on a regular basis (in months or years). Exercise was defined as any leisure time activities that included physical exercise regardless of whether these activities were performed alone, in a team, or a sports club, and examples were given (e.g., team sports either within or outside of a club, walking, swimming, horse riding, etc.). Mainly sedentary sports like chess, computer games or fishing were explicitly excluded from the definition.

#### *Habit Strength*

To measure general exercise instigation habit strength, the Self-Report Habit Index (SRHI; Verplanken and Orbell, 2003) was completed by study participants. However, three items on frequency of behavior from the original 12-item measure were excluded, as they have been subject to discussion in literature (Gardner, 2015) and since leaving them out did not change the main results of the original scale development studies

(Verplanken and Orbell, 2003). For the remaining nine SRHI-items, the wording of each item stem was "To go exercising is something..." and ended, for example, in one item at "... is something I do without thinking." Therefore, the scale rather taps the decision to go exercising than the execution of a specific exercise behavior (for a distinction between instigation and execution habit see the response to Hagger by Gardner et al., 2020). The scale showed a very good internal consistency of alpha = 0.917 and was approximately normally distributed. The scale did not address the same decision/behavior as the short weekly questionnaire. As habit strength for instigation habit was measured before the weekly course started, measuring the habit to attend exactly this course would not have made sense.

### Weekly Short Questionnaire

#### *Attendance*

The weekly attendance of each participant was recorded by a student assistant who attended every session (1 = present, 0 = absent, or missing when class did not take place). As a measure for frequency of behavior, we built a variable that indicated number of prior class attendance for every week. That is, for someone who attended the class for the second time, the variable "frequency of attendance" had a value of 1. We also coded the length of the interval until an individual attended the class again, with the unit of measurement being the opportunities to participate (since there were instances where a class did not take place for 1 week). For someone who came back regularly the next time, the length of time was coded 1, for someone who missed one opportunity before they came back, the length was coded as 2, and so on.

#### *Affective State*

Current affective states were measured by two items based on Russell's affect circumplex model (Russell, 1980). According to the model, two dimensions of affect need to be distinguished, namely affective valence and energetic arousal. Affective valence was measured through the Feeling Scale (Hardy and Rejeski, 1989). The question "How do you feel at this moment?" was answered on a scale of 1 (very bad) to 10 (very good). In the original version, response options range from −5 to 5, but we modified it to range from 1 to 10 to better align with other scales used in this research. Energetic arousal was measured by the Felt Arousal Scale (Svebak and Murgatroyd, 1985). The item read "How aroused do you feel at this moment?" and was answered on a 10-point scale of 1 (extremely tired) to 10 (extremely energized). According to Backhouse et al. (2007), the two scales have been widely applied and showed both satisfactory convergent and discriminant validity. Additionally, as further predictor of positive affect the increase in affective valence from the start to the end of the class (valence end minus valence start) was used. Positive values reflect an increase in valence during the class.

#### *Automaticity*

On a weekly basis, automaticity was measured at the beginning of the class. Participants were asked to rate how strongly they agreed with the following statement on a scale of 1 (not at all) to 10 (absolutely): "I arrived at the decision to attend the class today completely automatically (without thinking)." This single automaticity item is based on a similar measure employed by White et al. (2017) and derived from the automaticity subscale of the Self-Report Habit Index (SRHI) (Verplanken and Orbell, 2003; Gardner et al., 2012). This single item has shown adequate content and predictive validity (Verplanken and Orbell, 2003; Gardner et al., 2012), and was therefore chosen in order to keep the weekly questionnaire short for reasons of feasibility. The phrasing of the item is consistent with the concept of instigation (in contrast to execution) habits (Gardner, 2015). The decision to exercise is an important element of exercising behavior (Verplanken and Melkevik, 2008).

## Statistical Analysis

Data are described as means (M) and standard deviations (SD) for continuous variables and number (N) and percentages (%) for categorical variables.

Automaticity at a given participation week was predicted by affective state at the preceding participation in the exercise class. As the weekly data was nested within individuals, we used a two-level modeling approach, employing Mplus version 8 (Muthén and Muthén, (1998-2015)).

At the within-person level, automaticity was predicted by preceding affective valence, changes in affective valence during the preceding class, the cumulative frequency of subsequent participation, the length of the period from last attendance at the exercise class as well as the interaction between affect and frequency. Since automaticity was measured at each participation, the preceding automaticity was also included as predictor to adjust for autocorrelation over time.

As a predictor at the between-person level besides affect, baseline habit strength was used to adjust for differences in habit base level. Different sociodemographic measures were tested as predictors and included when meaningful. See **Figure 2** for the final model with interactions.

Research shows that positive changes during exercise are relevant for future exercise behavior (Schneider et al., 2009; Rhodes and Kates, 2015), however, contextual limitations lead us to conclude that we were not able to detect those dynamic changes (please refer to section "Discussion"). Due to high correlations of the three items which were completed at different times during the class, we could not include all of them in our model (see **Tables 1–3** for correlations). Rather, we used the measurement at the end of the class as well as the change in affect from beginning to the end as manifest variables in the prediction. Arousal and valence are seen as two orthogonal dimensions in the circumplex model. However, we found that both were highly correlated ($r = 0.714$) and could not be used in the same model because of multicollinearity. We therefore decided to examine both affect dimensions in separate models. However, in line with Feldman Barrett (Barrett, 2006), we suppose that valence is the most basic building block of emotional life and, therefore, expect it to have a greater influence on habit formation via motivational processes than energetic arousal, which may rather indicate the intensity of valence. Thus, the results presented here only refer to valence.

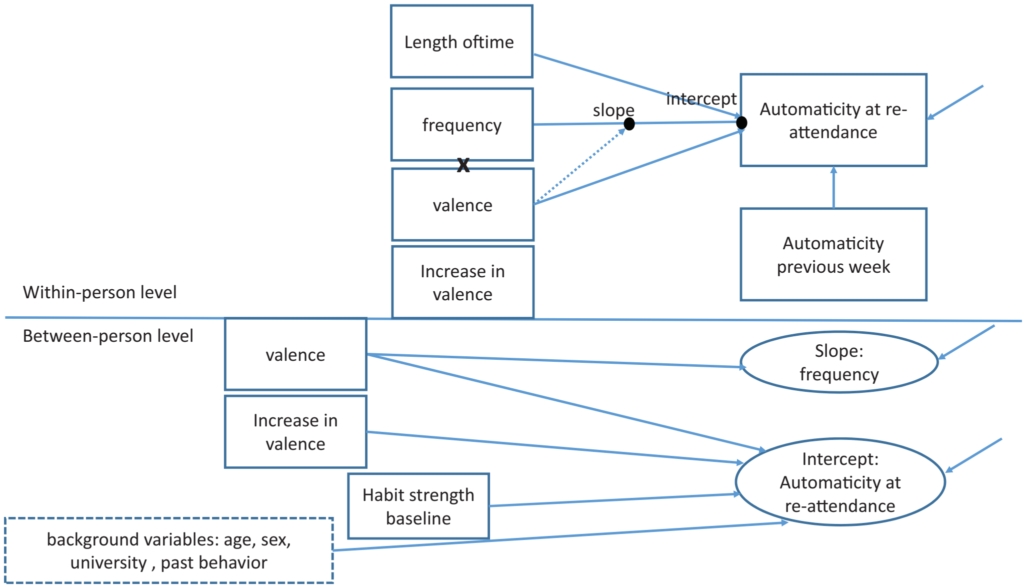


**FIGURE 2 |** Final model with interactions.

**TABLE 1 |** Correlations: within-person level.

| | SA | PA | AV3 | CF | DR | DV |
|---|---|---|---|---|---|---|
| SA | 1 | | | | | |
| PA | 0.292 | 1 | | | | |
| AV3 | 0.032 | 0.073 | 1 | | | |
| CF | 0.101 | 0.140 | −0.037 | 1 | | |
| DR | −0.074 | −0.112 | −0.029 | −0.080 | 1 | |
| DV | −0.019 | −0.096 | 0.626 | 0.033 | 0.041 | 1 |

*SA, subsequent automaticity; PA, preceding automaticity; AV3, affective valence (end of class); CF, cumulative frequency of participation; DR, duration until re-attending; DV, difference valence (increase in valence during participation in exercise class). The sample statistics for within and between refer to the maximum-likelihood estimated within and between covariance matrices, respectively.*

**TABLE 2 |** Correlations: between-person level.

| | HB | AGE | SEX | PB | UNI | SA | AV3 | DV |
|---|---|---|---|---|---|---|---|---|
| HB | 1 | | | | | | | |
| AGE | 0.158 | 1 | | | | | | |
| SEX | −0.151 | −0.188 | 1 | | | | | |
| PB | 0.435 | 0.304 | −0.149 | 1 | | | | |
| UNI | 0.100 | 0.220 | −0.110 | 0.253 | 1 | | | |
| SA | 0.335 | −0.101 | 0.049 | −0.030 | −0.483 | 1 | | |
| AV3 | 0.172 | −0.094 | −0.032 | −0.064 | −0.329 | 0.427 | 1 | |
| DV | −0.029 | −0.088 | 0.112 | −0.077 | −0.267 | 0.053 | 0.400 | 1 |

*HB, habit strength baseline (SRHI); PB, past behavior (regular exercising in months); UNI, University (1 vs. 2); SA, subsequent automaticity; AV3, affective valence (end of class); DV, difference valence (increase in valence during participation in exercise class). The sample statistics for within and between refer to the maximum-likelihood estimated within and between covariance matrices, respectively.*

Valence was used as a predictor at the within- as well as the between-person level. To this end the variable is decomposed into two latent components: At the between-person level a between covariance matrix is used where the variation between persons is captured by subtracting the overall mean from the latent person mean (grand mean centering). At the within-person level, a pooled within covariance matrix is used where the indicators are implicitly group mean centered. That is, the between component of a person is subtracted from the value at a given occasion.

We excluded those observations where no information on automaticity at the beginning of the class and no information on valence at the end of the preceding class were available. Other missing values were estimated implicitly using the full information maximum likelihood approach implemented in MPlus. Furthermore, we only included data from participants if one participation week was followed by re-attending the class, so that automaticity at the following participation could be predicted.

# RESULTS

## Descriptive Statistics

After the exclusion of missing observations, the final sample consisted of 1,082 observations from 226 individuals. 64.2% of the sample were females, 87.9% were students (percentage of valid answers, 44 were missing), 46% were from university 1, 54% from university 2, and the mean age was 24.46 ($SD$ = 5.25) years.

On average, each individual participated 6.8 times (range, 2–13). The intra-class correlation for automaticity was 0.360, that is about 36% of variation was between persons. See **Table 4** for descriptive statistics.

## Prediction of Automaticity

The candidate models for the prediction of automaticity at subsequent participation were tested in a stepwise manner.

**TABLE 3 |** Correlations: descriptive statistics of overall sample.

| | HB | AGE | PB | SA | PA | AV1 | AV2 | AV3 | AR1 | AR2 | AR3 | CF | DR | DV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HB | 1 | | | | | | | | | | | | | |
| AGE | 0.151 | 1 | | | | | | | | | | | | |
| PB | 0.447 | 0.315 | 1 | | | | | | | | | | | |
| SA | 0.203 | −0.053 | −0.017 | 1 | | | | | | | | | | |
| PA | 0.167 | −0.043 | −0.042 | 0.550 | 1 | | | | | | | | | |
| AV1 | 0.081 | 0.020 | 0.030 | 0.210 | 0.251 | 1 | | | | | | | | |
| AV2 | 0.139 | 0.029 | 0.005 | 0.185 | 0.227 | 0.510 | 1 | | | | | | | |
| AV3 | 0.054 | −0.033 | −0.019 | 0.185 | 0.196 | 0.370 | 0.625 | 1 | | | | | | |
| AR1 | 0.103 | 0.046 | 0.043 | 0.239 | 0.266 | 0.712 | 0.399 | 0.270 | 1 | | | | | |
| AR2 | 0.131 | 0.016 | −0.003 | 0.185 | 0.212 | 0.454 | 0.727 | 0.559 | 0.447 | 1 | | | | |
| AR3 | 0.061 | 0.002 | −0.022 | 0.163 | 0.218 | 0.269 | 0.509 | 0.715 | 0.251 | 0.630 | 1 | | | |
| CF | 0.069 | 0.096 | 0.027 | 0.073 | 0.141 | −0.100 | −0.093 | −0.080 | 0.034 | −0.101 | −0.017 | 1 | | |
| DR | −0.055 | −0.046 | −0.030 | −0.090 | −0.113 | −0.068 | −0.017 | −0.035 | −0.054 | −0.029 | −0.020 | -0.080 | 1 | |
| DV | −0.026 | −0.047 | −0.044 | −0.029 | −0.056 | −0.582 | 0.085 | 0.540 | −0.409 | 0.078 | 0.382 | 0.020 | 0.031 | 1 |

*HB, habit strength baseline (SRHI); PB, past behavior (regular exercising in months); SA, subsequent automaticity; PA, preceding automaticity; AV1-3, affective valence (three measurement time points); AR1-3, arousal (three measurement time points); CF, cumulative frequency of participation; DR, duration until re-attending; DV, difference valence (increase in valence during participation in exercise class).*

**TABLE 4 |** Descriptive statistics.

| Variable | N | Mean (*SD*) | Min–Max | Median |
|---|---|---|---|---|
| **Measured between-persons (time invariant)** | | | | |
| Habit strength baseline | 209 | 4.092 (1.401) | 1.00–7.00 | 4.11 |
| Past exercising (in months) | 203 | 87.394 (94.914) | 0–384 | 36 |
| **Measured within-person (time-varying, N is overall number of observations)** | | | | |
| Automaticity (at subsequent participation) | 1,082 | 6.893 (2.941) | 1.00–10.00 | 8.00 |
| Automaticity (at preceding participation) | 1,076 | 6.573 (3.127) | 1.00–10.00 | 8.00 |
| Frequency of attendance before (accumulated number of attended classes) | 1,082 | 2.987 (2.640) | 1.00–12.00 | 2.00 |
| Duration until re-attendance (opportunities, generally equals weeks) | 1,082 | 1.471 (1.048) | 1.00–12.00 | 2.00 |
| Increase in valence from beginning to end of class | 1,045 | 0.917 (1.850) | −6.00–9.00 | 1.00 |
| Valence (at end of class session) | 1,082 | 7.679 (1.629) | 1.00–10.00 | 8.00 |
| Arousal (at end of class) | 1,055 | 7.317 (1.862) | 1.00–10.00 | 8.00 |

*Overall, 1,082 observations from 226 persons were included. Number of observations for individual variables differs due to missing values.*

We first analyzed if age, sex, past behavior, and university predicted automaticity and, therefore, should be included as confounders. The only variable with a significant effect was university: the automaticity value from the university 2 subsample was estimated 1.520 points lower on average than at university 1 ($p < 0.0001$). All other potential confounders were not significant and thus not included in the final models. The variable university, however, distorted the model. We tested interaction effects with the other predictors of relevance. None of these interactions were approaching significance. We therefore decided to also exclude university as a predictor in favor of a more precise estimation. A model with age, sex, past behavior, and university had larger BIC (31632.3) and AIC (31402.9) values than the model without these background variables. Hence, we proceeded with the more parsimonious models without the tested background variables.

As described before, we restricted our models on valence as affective state variable, since including arousal caused multicollinearity and large standard errors. The separate model for arousal (not shown) achieved essentially the same results as the separate model for valence which is presented here.

The results of SEM models are shown in **Table 5**. We first tested the model with main effects only and then entered the interactions between number of sessions attended before (frequency) with valence on both the within- and the between-person level.

As can be seen in the right columns of **Table 5**, the interactions between cumulative frequency of participation with valence were not significant, neither at the within-person nor the between-person level. Both models did not differ in terms of a chi-square difference test [$\chi^2_{(df = 4)} = 0.69$, n.s.], but AIC and BIC values preferred the model with only the main effects. Although the estimated coefficients of both models were very similar, we focus on the results of the main effect model.

On the within-person level, automaticity was only predicted by preceding automaticity. None of the other predictors were

**TABLE 5 |** Results of the prediction model for valence.

| | Model with main effects | | | Model with interactions | | |
|---|---|---|---|---|---|---|
| | **Coefficient** | ***SE*** | ***p*-value** | **coefficient** | ***SE*** | ***p*-value** |
| **Within-person level fixed effects (weekly fluctuations)** | | | | | | |
| Automaticity previous attendance | 0.229 | 0.053 | < 0.001 | 0.210 | 0.069 | 0.002 |
| Duration until re-attendance | −0.084 | 0.080 | 0.294 | −0.085 | 0.081 | 0.292 |
| Frequency of attendance before | 0.038 | 0.028 | 0.169 | −0.039 | 0.177 | 0.825 |
| Valence end of class | 0.028 | 0.083 | 0.733 | −0.003 | 0.108 | 0.978 |
| Increase in valence during class | 0.018 | 0.063 | 0.778 | 0.022 | 0.065 | 0.740 |
| Valence × frequency | / | / | / | 0.011 | 0.023 | 0.629 |
| **Between-person level fixed effects** | | | | | | |
| Habit strength baseline | 0.298 | 0.090 | 0.001 | 0.303 | 0.091 | 0.001 |
| Valence end of class | 0.623 | 0.195 | 0.001 | 0.639 | 0.229 | 0.005 |
| Increase in valence during class | −0.367 | 0.181 | 0.042 | −0.376 | 0.189 | 0.047 |
| Cross-level interaction: Valence x frequency (slope) | **/** | **/** | **/** | −0.009 | 0.039 | 0.819 |
| **Random effects (variances)** | | | | | | |
| Residual variance automaticity within | 4.438 | 0.408 | < 0.001 | 4.316 | 0.414 | < 0.001 |
| Residual variance automaticity between | 1.747 | 0.454 | < 0.001 | 2.019 | 0.773 | 0.009 |
| Slope frequency | / | / | / | 0.014 | 0.034 | 0.671 |
| **Model fit information** | | | | | | |
| LL | −13499.424 | | | −13499.027 | | |
| AIC | 27058.849 | | | 27066.053 | | |
| BIC | 27208.446 | | | 27235.597 | | |

*Results from Mplus 8 using full information maximum likelihood estimation for cases with missing values. N = 1,082 observations from 226 persons, results of maximum likelihood estimation with robust standard errors. SE, standard error; LL, Log-likelihood; AIC, Akaike's information criterion; BIC, Bayes information criterion.*

significant. On the between-person level, we found automaticity to be predicted by baseline habit strength, preceding valence, and the change in valence during the preceding class.

### Prediction of Automaticity by Behavior Frequency

Cumulative frequency of prior class attendance as a measure of behavior repetition was not associated with an enhanced automaticity of the decision to re-attend the class (as indicator of habit strength).

There was a significant correlation between frequency and preceding automaticity (regression coefficient for frequency = 0.157, $p < 0.001$). In a model without preceding automaticity, frequency was significantly associated with subsequent automaticity (coefficient = 0.077, $p = 0.026$) although the effect was also small (overall model results not shown).

### Prediction of Automaticity by Affective States (Valence)

There was no association between valence and enhanced subsequent automaticity at the within-person level. This indicates that there was no change in automaticity for an individual after weeks where valence was especially high compared to other weeks. The same was true for an increase in valence during the preceding class, which also showed a non-significant effect on subsequent automaticity. However, significant associations were found at the between-person level. Individuals with a higher average valence (higher mean values over the weeks when participating in class) had higher automaticity values than those with lower mean valence, with a one-point higher mean valence score associated with a 0.62 point increase in automaticity (both measured on the same scale, $p = 0.001$). This effect was present after accounting for baseline habit strength as well as preceding automaticity. In terms of changes in valence during the class, our result pointed to persons with a higher average increase in valence during class, showing smaller automaticity values when re-attending (per one-point-increase expected automaticity went down by 0.37, $p < 0.05$).

### Prediction of Automaticity Through the Interaction of Frequency and Valence

There was no moderating effect of affect on the relationship between behavioral repetition and automaticity, as indicated by non-significant effects in the model with interactions on either level (**Table 5**). Neither was the association between behavioral frequency with automaticity strengthened after weeks when valence was higher, nor was this expectation approved between persons, that is, persons with higher average valence over the term did not show larger associations between behavioral frequency and subsequent automaticity.

## DISCUSSION

The purpose of this study was to examine the role of affective states and behavior frequency in the formation of real-world exercise instigation habits among adults. Overall, it could be shown that positive affect was significantly associated with subsequent automaticity, whereas behavior frequency did not significantly predict subsequent automaticity, and that affect did not significantly moderate the relationship between behavior frequency and automaticity.

With regard to our first hypothesis that behavior repetition will enhance automaticity, we did not observe a significant effect of frequency on automaticity. Two aspects need to be critically mentioned here. First, behavior frequency was rather low as participants attended the class on average only seven times (range 2–13). How long it takes to establish a habit is discussed in the literature (Walter, 2018; Hagger, 2019). In line with this discussion it is possible that in our study, behavior repetition did not occur often enough to enhance automaticity. Second, despite the non-significant prediction of automaticity, there was a significant correlation between frequency and preceding automaticity (about twice as large as with predicted automaticity at the within level), which might point to preceding automaticity masking the effect of frequency. In a model without preceding automaticity, frequency was significantly associated with subsequent automaticity although the effect was also small. Furthermore, in the model presented here, there was a minimal increase in the expected direction, i.e., for each exercise class visited, the resulting automaticity increased slightly. Additionally, we found the duration until re-attendance to be slightly negatively associated with automaticity. These tendencies are in line with other findings that support the role of behavior frequency for the formation of habits. One study that explored habit formation in a real-world setting found that repeating a behavior in a stable context increases automaticity (Lally et al., 2010). An asymptotic model best reflected the process of habit formation for 62 out of 82 individuals, and those study participants for whom this model provided a poor fit had shown lower behavior frequency during the time of the study. The finding that repeating a behavior leads to greater automaticity scores is also in line with the habit theory that suggests that habits are developed through the strengthening of a cue-behavior relationship (Verplanken, 2006; Gardner and Lally, 2018). Therefore, this cue-behavior association needs to be encountered at all which requires the enactment of a behavior when confronted with the cue and, in order to gain a degree of automaticity, needs to be repeated.

The second hypothesis stated that positive affect will enhance automaticity. Significant relationships were found for affective valence on the between-person level, but not on the within-person level. The non-significant effect on the within-level indicates that after weeks in which the valence score of a person at the end of class or the increase of affective valence during class was higher than usual for this person, there was no increase in the resulting automaticity. However, we found two significant effects on the between-person level and thereby added new insights on the role of affective states on automaticity development to the literature. First, for affective valence at the end of the class, the effect on the between-person level suggests that people who on average reported higher values in valence at the end of the class also had higher automaticity scores. One explanation for this is that individuals repeated the behavior more often because of the positive affect they associated with it and therefore built stronger habits. Theoretically, this assumption is supported by psychological hedonism of the past which states that formerly rewarded behavior is repeated more often in the future (Insko and Schopler, 1972). In their review, Ekkekakis and Dafermos (2012) concluded that affective responses to exercise, although measured in various ways due to methodological diversity, in fact predict subsequent exercise behavior. One study measured affective valence during and immediately following a brief treadmill walk at two time points (6 months apart) and found that affect reported during the walk was cross-sectionally and longitudinally associated with physical activity (Williams et al., 2012). Another study found that the relationship between intrinsic exercise rewards (such as enjoyment) and exercise behavior can be explained differently depending on the stage of adoption (Phillips et al., 2016). For initiators, this relationship was mediated by intentions, whereas it was mediated by habit strength for longer term exercisers (maintainers). Given that the participants in this study were unexperienced in terms of the specific instigation behavior, it is possible that positive affect strengthened their intentions to attend the course again. Due to the non-significant effect of frequency on automaticity, however, we cannot confirm that affect influences habit strength via behavior frequency. Therefore, other explanations are also possible, one of them being the possibility of a direct influence of affect on habit formation independent of behavior repetition and another one being methodological artifacts. We measured the two implicit constructs automaticity and affect on a weekly basis, one after the other, in one questionnaire. Depending on the answer a participant gave to the question of automaticity, they may have drawn conclusions about their affect, similar to what Gardner and Lally (2013, p. 494) call "a *post hoc* self-perception process." So possibly, habitual exercisers inferred positive affect from their habitual behavior whereas non-habitual exercisers reported no or less positive affect. Second, for the increase in affective valence during class, the effect on the between-level suggests that people who had a higher increase in valence had *lower* automaticity scores. Two lines of reasoning lead us to conclude that this result should not be over-interpreted. First, it was impossible to measure affective states multiple times during the exercise class as this would have meant a serious disruption of the flow of participants. We conclude that we were not able to detect dynamic changes in affect during exercise—although being aware that it would be desirable for future research (for recommendations regarding the timing of affect assessment see Ekkekakis et al., 2020). The affect assessment at the end of the class and the difference variable (after minus before) might therefore not reveal the true and differentiated affective response. However, one study also showed the tendency of affective responses *after* a hard-intensity task to be positively associated with future participation (Schneider et al., 2009). It should be investigated whether dynamic changes in the affective response during exercise influence habit formation. Second, further methodological concerns should be mentioned. That is, the affective state at the beginning of the class can be based on various reasons, while the state at the end of the class may more exclusively refer to the sports class itself. Subtracting these values from each other can therefore be problematic, and potential solutions discussed in the literature include a direct comparison operationalization (Peter et al., 1993), e.g., an item that directly asks for affective change.

The third hypothesis stated that positive affect may moderate the relationship between behavior frequency and automaticity. No significant moderation effects could be found, neither on the between-level nor on the within-level, and neither for affective valence at the end of the class nor for the increase of affective valence during class. These findings suggest that the relationship between frequency and automaticity does not differ depending on the degree of valence. In light of the above mentioned non-significant effect of affect on automaticity on the within-level and this non-significant moderation effect, our findings contradict parts of the assumptions of the Associative-Cybernetic Model (de Wit and Dickinson, 2009). The model suggests that there are two ways a reward can have an impact on habits. First, a reward should strengthen habits mediated by behavior repetition. Second, a reward should moderate the relationship between behavior repetition and habit. This could not be shown in our study. We speculate that this is because our study measured affective states *per se*, a mental but not cognitive or reflective phenomenon (Russell, 2003), while other studies that reported a moderation effect operationalized intrinsic rewards as cognitive constructs. For example, one study that confirmed the Associative-Cybernetic Model for fruit and vegetable consumption assessed intrinsic rewards by directly asking the participants whether the consumption was rewarding (Wiedemann et al., 2014). Gardner and Lally (2013) found that prior action was a stronger predictor of habit strength among participants who were of the self-determined motivational regulation type and showed autonomous motivation such as intrinsic interest. In line with our hypothesis on the moderation effect, they speculate that the enjoyment of intrinsically motivated PA may reinforce the past behavior-habit strength relationship. However, they did not measure enjoyment or any implicit constructs.

## Strength, Limitations, and Future Directions

One strength of this study is the weekly measurement of exercise class attendance over a period of 3 months in a relatively large sample. In order to understand habit formation, cross-sectional studies or observations for only a few weeks or at insufficient time points seem to be less appropriate. Further, the longitudinal design allowed us to explore the effects on a between- and within-subject level. Future studies should investigate the relationship between affective states, habit formation, and exercise maintenance by continuous measurement over an even longer period of time than in the present study. This would allow for examining the effects of affective states and habits on long-term adherence. Moreover, exercise class attendance was measured quasi-objectively by weekly observation of attendance so that we can rule out systematic bias of subjective measures of PA (Jekauc et al., 2014). The fact that we measured affective states rather than affective attitudes, affective judgments or anticipated affective responses which are not affective states *per se* (Ekkekakis et al., 2018) is also one of the several merits of this study. If one assumes that affect is not a cognitive or reflective sensation (Russell, 2003), it is not necessary to measure it as a cognitive construct: By asking participants to reflect about their affective attitudes or judgments, however, the answer is the result of cognitive operations (Ekkekakis et al., 2018). Applying the Feeling Scale (Hardy and Rejeski, 1989) and Felt Arousal Scale (Svebak and Murgatroyd, 1985), we are coming closer to measuring affective states *per se* and thereby extend the literature on the role of affect.

This study was an observational one which cannot prove causality, although future events were predicted from preceding ones. A potential shortcoming of the present study is the rather high percentage of missing values. Since we only collected data from those individuals who attended the class, there is no information about the reasons for the absence of the missing participants. Therefore, we do not know whether the missing is random, due to a lack of habit formation or other reasons. One promising approach to gather information about reasons for a dropout are real-time analyses and feedback from wearables (Ebner-Priemer et al., 2019). However, it is possible that the lack of motivation to attend the exercise course is associated with the lack of motivation to participate in the study. Furthermore, the 2-weeks Christmas holidays in the middle of the semester led to a break, which is another limitation. As habits form due to repeated performance in stable contexts (Aarts and Dijksterhuis, 2000; Wood and Neal, 2007), the break might have represented an interruption in habit formation. Again, no data is available of the participants during the break. However, we found no indication of a drop in automaticity after this break. Another, rather controversial limitation lies in the methodology for measuring habits. In this study, baseline habit and weekly automaticity scores were measured by self-report. Whether it interrupts or hinders the formation of habits when weekly questions are asked about the automaticity of a process that is actually supposed to be no longer reflective, can be questioned critically. Also, some scientists have reported that subjective insights into unconscious processes may be lacking precision (Hagger et al., 2015) and some found comprehension and recall problems in participants' responses to self-report habit measures (Gardner and Tang, 2014). Others, however, argue that individuals are able to reflect on automatically occurring behaviors and can interfere habit from its salient consequences, the habitual behavior that they show, although they were not thinking about it (Verplanken and Orbell, 2003; Sniehotta and Presseau, 2012). Alternative measures of automaticity need to be developed in future research with a special focus on their feasibility in long-term studies. Another limitation concerning the methods are the single-item scales used in this study to measure automaticity, affective valence, and arousal. Given that valence and arousal turned out to be strongly correlated, it must be critically noted that the scales were not appropriate for differentiating between the two dimensions that are actually considered orthogonal in the circumplex model (Russell, 1980). One explanation for this could be that we failed to explain the not very intuitive concept of arousal to the participants and, in particular, to describe its difference to valence (Ekkekakis and Petruzzello, 2002). Ekkekakis and Petruzzello (2002) note that exercise is able to change perceived activation and that these changes can lead to either positive or negative valence making it necessary to distinguish between the two dimensions of affect. However, since we were not interested in a differentiated pattern of affect as a dependent variable, but in this study focused on affect as a determinant of habit formation, the lack of specification appears to be negligible. Weighing the pros and cons of single-item measures, Ekkekakis and Petruzzello (2002) further mention that they pose a risk of random measurement error. However, important to our study was the assumption that given their compactness they do not induce reactivity to weekly testing. Regarding the measure for past exercise behavior used in this study, it can be critically mentioned that the definition of exercise given in the questionnaire was rather wide compared to the definition by Caspersen et al. (1985), which contains, different from our definition, the planned, structured, and repetitive nature of exercise.

## Implications

According to Gardner and Lally's (2018) model of habit formation, individuals first need to form an intention when deciding to act; second, they need to initiate the action which requires mobilization of self-regulatory resources; third, they need to repeat the behavior for the strengthening of cue–response associations. In the present study, we focused on behavior repetition and affect as determinants of habit formation. Thus, the future research and practical implications that can be derived from this study and the literature that emphasizes the role of behavior repetition can be divided into two areas: Exercise promotion interventions and practitioners should design and implement interventions that result in (a) behavior repetition, and (b) a positive affective response to exercise. We suppose that the latter leads to behavior repetition. However, other important aspects of behavior maintenance include skills required to translate intentions into action, such as inclusion of self-monitoring in combination with other self-regulatory techniques, e.g., specific goal setting (Michie et al., 2009). In order to attain a goal, implementation intentions have been proven to have had a positive effect (Gollwitzer and Sheeran, 2006). Future studies should explore how to best design an exercise program that elicits regular positive affective responses in the participating individuals, as this is still one of the major challenges in this field. One possibility is to focus on the role of teachers or coaches for the development of positive affect of exercise class participants. The manipulation or education of teachers' feedback (Leisterer and Jekauc, 2019), their leadership style (Raedeke et al., 2007), and their social-emotional skills (Strauch et al., 2018) are promising approaches. One study found four facilitators of positive emotional experiences of sport and exercise participants: perceived competence, perceived social interaction, novelty experience, and perceived physical exertion (Wienke and Jekauc, 2016). Furthermore, in one study, enjoyment after a theory-based "novel" physical education lesson that included evidence-based modifications, such as music, was higher than after a "traditional" physical education lesson, despite no significant differences in amount and intensity of PA components (Vazou et al., 2019). Future studies should investigate the relationship between affective states, behavior frequency, and habit formation by other measurements than self-reports and over a longer period of time, to explore the role of habits in long-term behavior maintenance. Since there is no such thing as a global physical activity habit (Gardner et al., 2020), this study focused on automaticity as an indicator of instigation habits. However, deeper understanding on the different habitual behavior sequences and their interplay with intention or other cognitive and automatic constructs is needed to progress further to a theory of habit that is still missing in the field.

# CONCLUSION

In conclusion, the present work discusses the importance of affective valence and behavior repetition in the formation of instigation habits in exercise contexts. Thus, interventions designed to encourage long-term behavior maintenance via habit formation processes, which are required for achieving sustainable health benefits, should try to elicit positive affective responses.

# DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

# ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethik-Kommission der Universität Bielefeld (EUB), Ethics Committee of the Bielefeld University, Bielefeld University, Bielefeld, Germany. The patients/participants provided their written informed consent to participate in this study.

# AUTHOR CONTRIBUTIONS

SW wrote the manuscript. SW, EF, and DJ conceptualized the study. EF and DJ organized the data collection. EF conducted the statistical calculations. All authors helped to edit the manuscript and approved the final version of the submitted manuscript.

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SYSTEMATIC REVIEW
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# Can Positive Affective Variables Mediate Intervention Effects on Physical Activity? A Systematic Review and Meta-Analysis

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Well-developed theories are necessary to guide the public in increasing physical activity (PA) and promoting physical health. The role of positive affective variables (PAVs) in exercise is gaining more attention, but none of the literature has provided a systematic review and quantitative analysis of its mediating role. Therefore, the purposes of this study are (1) to systematically review studies of PA interventions, that use PAVs as the mediating variables, in order to evaluate and provide narrative summaries of these studies; (2) to statistically synthesize evidence for the mechanism of the effects of PAVs on PA outcomes. To conduct an extensive search, a PRISMA-compliant protocol was completed, and five electronic databases had been searched by 1 April 2020. We used a two-stage structural equation modeling (TSSEM) analysis approach to test how interventions trigger the critical PA change process to influence outcomes. The search strategy generated 1,732 papers potentially relevant to this study; forty of these studies met the data extraction criteria for meta-analytic mediation analysis. The path coefficient from intervention to PAV $a = 0.26$ (95% CI = 0.08 to 0.44), the path coefficient from PAV to PA $b = 0.21$ (95% CI = 0.13 to 0.28), and the direct effect from intervention to PA is also significant ($c = 0.19$, 95% CI = 0.12 to 0.26). In addition, the indirect effect of intervention on PA via PAV was statistically significant ($c' = 0.05$, 95% CI = 0.02 to 0.10). This reveals that PAVs partially mediate the relationship between interventions and PA. Our study is the first to systematically summarize the effects of experimental studies to increase PA through PAVs. It is highly recommended to make future interventions more innovative and to target the PAVs as mediators with higher fidelity.

**Keywords: intervention, positive affective variable, physical activity, mediation, meta-analysis**

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## INTRODUCTION

A growing body of empirical research shows that regular physical activity (PA) is effective in improving a range of clinical and non-clinical health-related outcomes, including metabolic disorders (Denham et al., 2016), cardiorespiratory fitness (Shuval et al., 2014), arterial stiffness (Boreham et al., 2004) and physical and psychological well-being (Penedo and Dahn, 2005). Indeed, though PA is so fundamental to human's health, a minority of adults report engaging in PA at a level compatible with public health guidelines, countering the 50% of people who stop exercising within the first 6 months of starting an exercise program (Finne et al., 2019). Physical activity maintenance has proven to be a daunting and enduring challenge for PA and public health professionals, as the benefits of PA depend entirely on constant engagement (Annesi, 2003). Therefore, the psychological mechanism that underlies PA persistence has come into sharp focus.

To date, the dominant theoretical approaches employed to intervene in PA include the social cognitive theory (Bandura, 1998), the theory of planned behavior (Ajzen, 1991), and the transtheoretical model (Prochaska and Velicer, 1997). However, even as the most predictable framework, social cognitive theory, on average, can only explain 20% of the variance in PA maintenance (Jekauc et al., 2015). The dominance of these theories hinders the development of theories, because they focus merely on cognitive mechanisms and neglect the role of affective variables (Jekauc and Brand, 2017). Thus, an extension of the theories for affective variables seems inevitable (Jekauc et al., 2015). Considering that many exercisers are susceptible to negative affects during PA procedures (Ekkekakis and Acevedo, 2006; Rose and Parfitt, 2010), an emphasis on positive affects may have a positive impact on adherence to exercise with inevitable motivational effects. Somewhat also related to this notion, Parfitt and Hughes (2009) elucidated the implications of the peak-end rule, which states that the affective experience of an exerciser can have a potent effect in guiding future participation decisions (Williams et al., 2012) via the proposed mechanism of affective memory (Fredrickson and Kahneman, 1993).

Primarily, the words emotional or affective apply, to varying degrees, to an ill-defined, board, and heterogeneous aggregate of phenomena (Fehr and Russell, 1984). Today, we consider the term of affect concerning a neurophysiological state that is consciously accessible as a pure primitive non-reflective feeling (Russell and Barrett, 1999). In contrast, emotion refers to feelings that are typically brief, intense, and attributable to an apparent cause (Beedie et al., 2005). Rather than thinking about emotional feelings in terms of categories, an alternative way to organize them is to arrange them along dimensions. Emotions can be conceptualized in the form of several dimensions, and these dimensions can be independent of each other, such as positive and negative activation (Watson et al., 1999), or positivity and negativity (Cacioppo and Gardner, 1999). According to existing research, the proximity-avoidance distinction is applicable in emotions (positive and negative affective dispositions) (Watson et al., 1999), and the neurological basis for this distinction between motivation and emotion has been demonstrated through affective neuroscience (Davidson, 2003). As stated by Larsen et al. (2008), "motivation and valence tend to be correlated, such that positive emotions are associated with approach and negative emotions with avoidance." For these reasons, we will concentrate on affective variables, not on negative affective variables. In other words, this paper will generalize non-negative, positive affects, emotions, and feelings, and will use the term positive affective variables (PAVs) to refer to them.

The effects of PAVs have been subject to investigation in behavior change contexts, resulting in several theoretical and empirical studies. According to van Cappellen et al. (2018), the upward spiral theory of lifestyle change states that positive affect experienced during health behaviors increases incentive salience for cues associated with those behaviors, which in turn, implicitly guides attentions and the everyday decisions to repeat those behaviors. Fredrickson's broaden-and-build theory argues that positive affect builds a suite of endogenous resources, which may, in turn, amplify the positive affect experienced during positive health behaviors and strengthen the non-conscious motives. Similarly, consistent with hedonic theories of behavior (Cabanac, 1992), where persistent behaviors are considered to be determined by positive reinforcement, core affective valence in response to PA has been posited as an essential determinant of future PA behavior (Bryan et al., 2007; Williams, 2008). Empirical studies also supported this idea; for example, Klusmann et al. (2015) found that the fulfillment of emotional outcome expectancies emerges as a significant predictor of adoption and maintenance of PA. Similarly, Schutte et al. (2017) found that positive affective responses were associated with higher amounts of regular exercise activity and that this association was accounted for by an overlap in genetic factors influencing affective responding and exercise behavior.

In contrast to the broad evidence base for PAVs' effectiveness, relatively few studies have tested the mechanisms of PAVs in exercise interventions. Mediators have been defined as intervening variables in the causal process or pathway between intervention and PA (Diener and Emmons, 1984). Given its propensity to optimize intervention effects through identifying potential psychological mechanisms underlying PA intervention, matching exercise intervention prescription to the theoretical framework, and strengthening active components of interventions during PA seems reasonable. It is a worthy venture to investigate PAV as a mediator of PA outcome (Kazdin, 2007).

So far, three reviews have summarized the classification of mediators of PA (Lewis et al., 2002; Rhodes and Pfaeffli, 2010; Murray et al., 2018); however, research into the mediation role of PAV have been narrow, incomplete, and problematic, due to the somewhat limited sample size. For instance, Lewis et al. (2002) examined three studies that investigated enjoyment as a mediator of intervention and PA and indicated that two of them were not significant. Murray et al. (2018) integrated findings with experimental data to propose that the mechanism through emotion works, and wherein half of the empirical studies reported significant findings. Nonetheless, Klos et al. (2020) and Rhodes and Pfaeffli (2010) showed moderate evidence of interventions in increasing enjoyment and PA. In contrast, the mediating effect of PAV in exercise interventions remain to be examined. Therefore, the purpose of this study is two-fold. First, it aims to systematically review studies of PA interventions that use PAV as the mediating variable to evaluate and provide general summaries (study, participant, measurement, and intervention characteristics) of these studies. Of which, study and participant characteristics include research setting, PA level at baseline, percentage of female subjects, sample size, and mean age; measurement characteristics include types and methods of

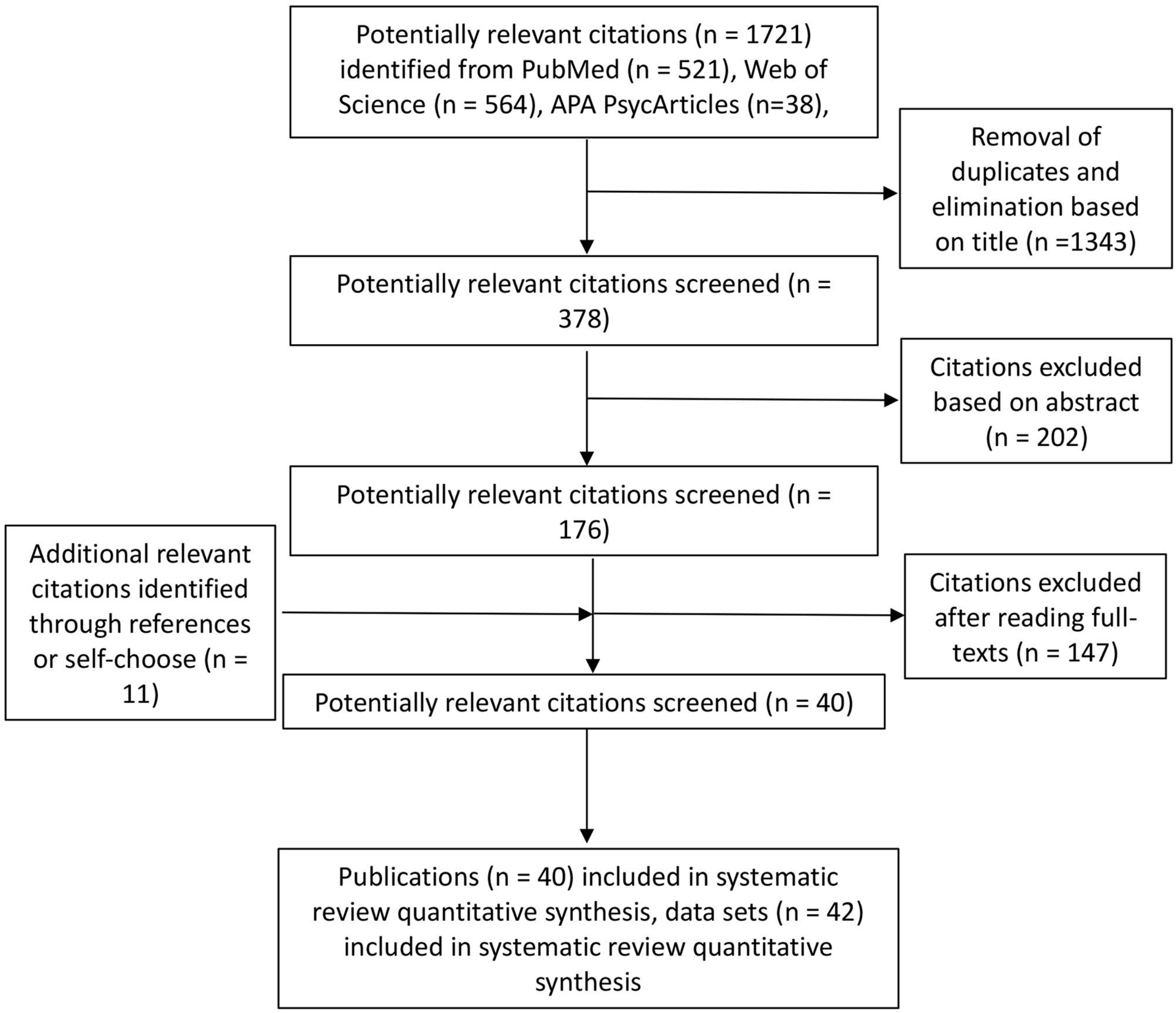


**FIGURE 1 |** PRISMA flow diagram for articles identified, screened eligible, and included in this paper.

PA and PAV measurement; intervention characteristics include theory, length of intervention, and behavior change techniques used in each study). Second, it aims to statistically synthesize evidence for the mechanism of the effect of PAV on PA outcome. The combination of statistical synthesis and narrative summaries of existing mediation findings will allow us to draw more reliable and comprehensive conclusions about how PAVs improve PA, compared to using either one of these techniques in isolation (Gu et al., 2015).

# METHODS

## Search Strategy

A protocol using the PRISMA standards (Moher et al., 2009) was completed before initiating the literature search (**Figure 1**). A comprehensive search of published studies up to 01/04/2020 was conducted using the following electronic databases: Web of Science, PubMed, PsycINFO, PsycArticle, and Psychology and Behavioral Sciences Collection. The search term was: (1) Intervention OR Trial OR Experiment; (2) Physical Activity OR Exercise; (3) Enjoy* OR Affect* OR Emotion* OR Mood* OR Feeling; (4) Mechanism* OR Mediat* OR Predict* OR Process* OR "Structural equation modeling" OR Caus* OR Path* OR Correlat* OR Relationship OR Associat*; (5) NOT (Patient* OR Cancer OR clinical OR disease* OR Illness OR Depression OR Rat OR Mouse OR Protocol OR Cell OR Bone* OR Blood OR Rehabilitation OR Disorder* Injur* OR HIV OR Carbohydrate OR Athlete* OR Player* OR Runner* OR Review OR Comment OR Therapy); (6) 1 AND 2 AND 3 AND 4 AND 5.

For inclusion, each study was required to meet the following criteria: (1) intervention studies that assessed the PAV as a putative mediator of PA; (2) studies' objectives were to increase lifestyle or recreational PA through affective variables not for competitive sports or fitness; (3) information needed to calculate effect sizes must have been made available for PAVs and PA (PA measurement could be self-reported or objective measured, e.g., accelerometer readings); (4) participants are from a healthy population (non-clinically defined populations, obese or pregnant populations were also excluded); (5) written in English;(6) original, peer-reviewed studies. Furthermore, similar dimensions (e.g., positive affect, PA enjoyment, PE enjoyment, revitalization, positive engagement, and remembered pleasure) were identified as PAVs, and negative affective variables were excluded. We intentionally selected the shortest duration of 10 min for PA, given that 10 min is the shortest recommended duration of exercise to elicit health benefits (Edwards and Loprinzi, 2019).

To evaluate mediators between intervention and PA, an additional criterion was established based on Murray et al. (2018). An included study had to involve at least one of the following: "(a) formal mediation tests, (b) examined association of putative mediators (or mediator changes) with PA outcomes (or PA changes), (c) examined intervention effects on putative mediators."

## Data Extraction and Data Analysis

Searches were completed and the eligibility of each study was determined by the first author. Abstracts were cross-checked against the inclusion criteria. Where the first author was unsure of relevance, the abstract was retained, and decisions regarding inclusion and exclusion were resolved by discussion with the last author. A study that can fulfill the data extraction criteria below is eligible for our meta-analysis.

According to Stone et al. (2019), stratification by quality in meta-analysis leads to a form of selection bias (collider stratification bias), and it is recommended for inclusion in all eligible studies rather than removing studies with low-quality ratings. Therefore, this paper does not evaluate and grade the studies' quality but includes all eligible studies.

To understand how change occurs during interventions, evaluating mediation effect is essential [i.e., how an intervention (X) influences an outcome (Y) through a mediator (M)] (Kazdin, 2007). Accordingly, we used a two-stage structural equation modeling (TSSEM) approach to test how interventions trigger the critical PA change process to influence outcomes (Cheung, 2014). The metaSEM package in R was used to perform our analyses (Cheung, 2019). In the first stage, we combined the relative effect sizes into matrices to calculate a pooled correlation matrix; the second stage involved treating the pooled matrix as the observed correlation matrix and fitting a structural mediational model to the matrix to test the fit of the model to the data. The specification of any structural model in the metaSEM package is done by using two matrices, of which matrix A specifies all regression coefficients in the model, and matrix S specifies all variances and covariance in the model (McArdle and McDonald, 1984). The procedure used is as explained by Jak (2015).

In the preparation phase, the bivariate correlations between X (intervention vs. control/pre-intervention), intervention change in PAVs (M), and PA (Y) were extracted from each relevant study. If a study did not explicitly report bivariate correlation coefficients, we used t-statistics, *F*-statistics, means, standard deviations, and effect sizes to calculate bivariate correlations (Lipsey and Wilson, 2001). Studies in which only reporting regression coefficients were omitted from the mediation analysis, as results from both the existing meta-analysis and the Monte Carlo simulations revealed that beta estimation procedures were associated with potentially significant biases (Peterson and Brown, 2005; Roth et al., 2018). To ensure that the observations in the sample were independent (Hunter and Schmidt, 2004), only one PAV/PA outcome was selected from each study to enable bivariate correlations to be extracted. Although it would be possible to calculate mean correlations across multiple outcomes in a single study, it would not be straightforward to determine the appropriate sampling variance of averaged correlations. Besides, we collected descriptive data from the included studies, such as setting, subjects' PA level at baseline, percentage of female subjects, the theoretical basis of the intervention, and PAV and PA measurement types and methods. In particular, the PA level at baseline can be divided into four categories according to whether the subjects meet a PA guideline (which can be defined arbitrarily by each study): not meeting PA guideline at baseline, meeting PA level at baseline, mixed and unreported. In order to gain a clearer understanding of the studies' intervention methodologies, we extracted data for each study's behavior change techniques based on Michie et al. (2011) 40-item taxonomy. The coding of the behavior change techniques was also primarily done by the first author, but for those codings that could not be determined by the first author, decisions were discussed with the last author.

# RESULTS

## Study Flow and Characteristics

The search strategy generated 1,732 papers potentially relevant to this study; we excluded 1,692 papers following the eligibility criteria (e.g., unrelated topics, chronic condition, qualitative studies, insufficient data). After initial exclusions, there were 176 articles for full-text review, of which 11 were identified by cross-referencing. Of the 40 included studies which fulfilled the data extraction criteria of meta-analytic mediation analysis (see **Figure 1** and Appendix 3 in **Supplementary Material**), two included a measure of two independent subgroups (Digelidis et al., 2003; Hutchinson et al., 2018). Hence, a total of 42 data sets were elicited for analyses.

A summary of the data from the 40 articles included in this paper is presented in Appendix 1 in **Supplementary Material**. In terms of the participants' age, four age intervals were designed for distinguishing and classifying the mean age of each study; they are the interval of study mean age below 18 ($n = 18$), the interval of study mean age between 18 and 35 ($n = 13$), the interval of study mean age between 36 and 60 ($n = 7$), and the interval of study mean age over 60 ($n = 2$). In terms of gender distribution, just one study identified its gender as male and ten studies delimited their gender as female, the genders of the subjects in the remaining 28 studies were mixed. In terms of physical activity at baseline, we marked out four classifications as "not meeting

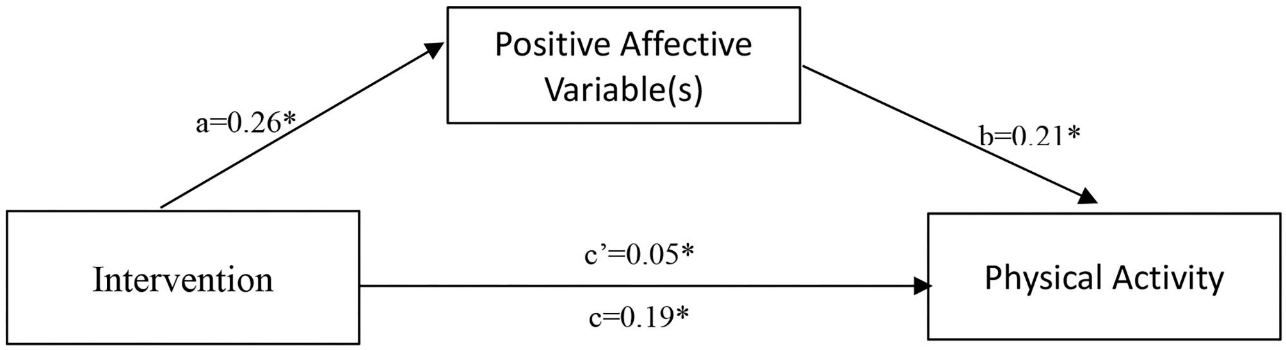


**FIGURE 2 |** Path diagram depicting the mediational model for intervention to PA with PAV(s) as the mediator. Values are path coefficients. *$p < 0.05$. a = "path coefficient from intervention to PAV," b = "path coefficient from PAV to PA," c = "direct effect from intervention to PA" and c' = "indirect effect from intervention to PA."

PA guidelines at baseline" ($n = 18$), "meeting PA guideline at baseline" ($n = 3$), "mixed" ($n = 9$), and "unreported" ($n = 10$). Besides, the primary constructs of mediating variables (PAVs) measured in these studies were enjoyment ($n = 25$), affect ($n = 5$), affective attitude ($n = 4$), affective valence ($n = 2$), exercise-induced feeling ($n = 1$), remembered pleasure ($n = 1$), and mood state ($n = 1$). Thirty-six intervention studies explicitly mentioned theoretical underpinnings in their descriptions; the other four intervention studies did not mention any framework. The most commonly used theoretical frameworks were: the social cognitive theory ($n = 12$), the self-determination theory ($n = 8$), the transtheoretical model ($n = 7$), the theory of planned behavior ($n = 7$), and the dual-mode model ($n = 6$). Approximately 60% of the studies were conducted in schools or at universities ($n = 24$), the remaining study settings varied (such as in laboratories, communities, outdoors, workplaces, internet, homes, gyms).

The intervention techniques employed by each study are summarized in detail in Appendix 2 in **Supplementary Material**. According to Michie et al. (2011), the 40 studies used 2 to 17 behavior change techniques, of which five studies employed no more than three behavior change techniques, 27 studies employed 4 to 10 intervention techniques, and 18 studies employed more than ten behavior change techniques. In terms of the frequency of use of each behavior change technique, the most commonly used intervention techniques were (1) provide instruction on how to perform the behavior ($n = 32$), (2) action planning ($n = 25$); (3) Model/demonstrate the behavior ($n = 24$); (4) Plan social support/social change ($n = 23$); (5) Stress management/emotional training ($n = 21$). However, five other behavior change techniques were not employed by any of the included studies: (1) Prompt generalization of a target behavior; (2) Prompt identification as a role model/position advocate; (3) Prompt anticipated regret; (4) Fear arousal; (5) Stimulate anticipation of future rewards.

## The Mediating Role of Positive Affective Variables

We then report the results of the TSSEM analysis in a stepwise sequence. For calculating the pooled correlation matrix, we used the 42 correlation matrices. In a first step, we tested a

**TABLE 1 |** Pooled correlation coefficients ($k = 42$) for X (participants in post-intervention vs. post-control/ pre-intervention), M (PAV) and Y (PA).

| | X | M | Y |
|---|---|---|---|
| X | 1 | | |
| M | 0.26** | 1 | |
| Y | 0.25*** | 0.26*** | 1 |

*$^{**}p < 0.01$, $^{***}p < 0.001$.*

fixed-effects model. The $\chi^2$ of the model with equality constraints on all correlation coefficients across studies was significant $\chi^2_{(45)} = 196.48$, $p < 0.01$, CFI = 0.719, CLI = 0.701, and the RMSEA was larger than 0.10, indicating a bad suitability. Thus, the random-effects model seems more appropriate (Harrer et al., 2019). The total pooled sample size was 9,235. The averaged correlation matrix based on the random-effects model was shown in **Table 1**. According to Gignac and Szodorai (2016) suggested that in interpreting statistical results, correlations of 0.10, 0.20, and 0.30 should be considered relatively small, typical, and relatively large, and we found medium-sized overall correlations between intervention and PAV ($r = 0.26$, $p < 0.01$), PAVs and PA ($r = 0.25$, $p < 0.001$), and intervention and PA ($r = 0.25$, $p < 0.001$).

In stage 2, we used the pooled correlation matrix to fit the hypothesized structural model. **Figure 2** displayed the path diagram of the mediational model. The path coefficient from intervention to PAV $a = 0.26$ (95% CI = 0.08 to 0.44), the path coefficient from PAV to PA b = 0.21 (95% CI = 0.13 to 0.28), and the direct effect from intervention to PA is small but significant ($c = 0.19$, 95% CI = 0.12 to 0.26). In addition, the indirect effect of intervention on PA via PAV was small ($c' = 0.05$, 95% CI = 0.02 to 0.10). Since zero is not included in the 95% confidence interval, the indirect effect can be considered small but significant. This provides evidence for partial mediation (Diener and Emmons, 1984).

# DISCUSSION

These investigation's aims are two-fold. First, it aims to systematically review studies of PA interventions that use PAVs as the mediating variables to evaluate and provide narrative summaries of these studies. In these 40 included studies, similar constructs (e.g., positive affect, affective attitude, PA enjoyment, vigor, activation, excitement) were grouped into PAVs to serve as mediating variables for the PA interventions. The narrative review revealed that in exploring the mediating role of the PAVs, the vast majority of studies had focused more on the role of enjoyment and less on other similar constructs (e.g., vigor, activation, excitement). Moreover, the majority of research subjects are students, limiting the diversity of subjects in such research, although it is easier for schools and universities to conduct experiments. Besides, only one study has focused on PAV's effect on male PA outcomes, and relatively few studies have accurately analyzed the mediating role of PAVs on the male PA outcomes. So far, we have not found a comparison of the mediating effects of PAVs on PAs between males and females, and perhaps this is a direction worth exploring. Finally, the study found a considerable variation in the frequency of use of each behavior change technique in included studies, with some being utilized by more than one-third of all studies, while the other five were not utilized by any included studies. A more detailed review summarizing the effects of each behavior change technique on PAV and PA has yet to be completed; furthermore, rigorous experimental testing using factorial designs to isolate and incorporate unique techniques is also necessary.

Second, it aims to statistically synthesize evidence for the mechanism of the effect of PAV on PA outcome. To achieve this, we constructed a framework that predicted that intervention would have initial effects on the proximal outcome or mediating mechanism (PAVs) and the distal outcomes (PA). The results showed a significant and moderate effect of PAV as a mediating variable for the PA intervention, suggesting that PAV plays a unique role in determining PA. It is a juxtaposition of findings: (a) intervention was positively associated with PAV; (b) PAV was positively associated with PA outcome; (c) intervention was positively associated with PA outcome. Those findings broadly supported the work of other studies in this area linking PAV with PA. For instance, according to Williams (2008), affective response to exercise is posited to influence exercise adherence via anticipated affective response to future exercise. Similarly, Lee et al. (2016) proposed a two-pronged approach to PA promotion. They posited that more likely those strategies result in more positive affective responses to exercise as well as better adherence of participants to exercise. These findings are also consistent with the principle of hedonism, which states that individuals seek to maximize enjoyment and minimize pain (Higgins, 1997). In the light of the current research findings that contemplate this principle, the primary purpose of PA promotion interventions is to facilitate enjoyment rather than physiological benefits (Nielsen et al., 2014), which seems sensible. Over the past decade, there has been an upsurge of enthusiasm for considering the role of positive emotions and affects in the prescription of PA more fully (e.g., Ekkekakis et al., 2013, 2020). An underlying message of these sources is that if individuals are not motivated by self-determined influences, such as enjoyment, then they are less likely to engage in long-term PA, no matter how often they are informed of its potential health benefits (Brand and Ekkekakis, 2018). Therefore, exercise interventions that promote self-determination (Ryan and Deci, 2000) have the potential to promote the maintenance of PA behaviors. In conjunction with previous meta-analysis reviews of affective variables or affective judgments (Nasuti and Rhodes, 2013; Rhodes et al., 2019b), and findings from previous meta-analyses of PA interventions (Conn et al., 2011), these studies support the central role played by PAVs.

## LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

To reduce the possibility of selection bias, we used systematic and comprehensive search techniques to locate studies, although it may not be possible to identify all substantial investigations. The decision to exclude studies published in languages other than English was considered a minor limitation. Besides, this paper focuses on subjects in non-clinical states and does not explore and calculate the mediating effects of PAVs on clinical exercise interventions. Such studies would hold particular value, if they focused on clinical populations, including diabetics, the clinically obese, and other patients recovering from surgery (Hutchinson et al., 2017). Furthermore, given that most of the subjects in the studies included in this paper were female or of mixed-gender, it is also necessary to distinguish between the role of PAVs for male and female exercise in future studies.

## CONCLUSION

Overall, the findings suggest that intervention can moderately increase PAV in exercisers, PAV can moderately boost PA in exercisers, intervention can slightly increase PA in exercisers, and PAV partially mediates between intervention and PA improvement. Given the summative evidence in the research literature supporting PAVs for a range of PA outcomes, it is reasonable to conclude that PAV increasement intervention has the capacity to provide considerable positive effects for exercisers to improve PA outcomes. This study has identified and highlighted that PAV can be a mediator between intervention and PA, which means that we can direct better and stronger interventions that trigger key PA change processes. Thus, it is strongly recommended that future interventions be more innovative and aim for higher fidelity with PAV as a mediator.

## DATA AVAILABILITY STATEMENT

All datasets presented in this study are included in the article/**Supplementary Material**.

## AUTHOR CONTRIBUTIONS

DJ and CC contributed to conception and design of the study. DJ supervised the entire process. CC organized the database, performed the statistical analysis, and wrote the manuscript. EF and AK supported CC in data extraction and data analysis phase. DJ, EF, and CC contributed to manuscript revision. All authors read and approved the submitted version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.587757/full#supplementary-material

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# Motivation States for Physical Activity and Sedentary Behavior: Desire, Urge, Wanting, and Craving

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To better explain daily fluctuations in physical activity and sedentary behavior, investigations of motivation are turning from social cognitive frameworks to those centered on affect, emotion and automaticity, such as the Affect and Health Behavior Framework (AHBF), Integrated Framework and Affective-Reflective Theory (ART). This shift has necessitated: (a) re-examination of older theories and their constructs, such as drives, needs and tensions and (b) an inspection of competing theories from other fields that also attempt to explain dynamic changes in health behaviors. The Dynamical Model of Desire, Elaborated Intrusion Theory and others commonly share with AHBF the idea that human behavior is driven strongly by *desires* and/or the similar concepts of wants, urges, and cravings. These *affectively-charged motivation states* (ACMS) change quickly and may better explain physical activity behavior from one moment to the next. Desires for movement predominantly derive from negative but also positive reinforcement. Data from clinical populations with movement dysfunction or psychiatric disorders provides further evidence of these drivers of movement. Those with Restless Legs Syndrome, akathisia, tic disorders and exercise dependence all report strong urges to move and relief when it is accomplished. Motor control research has identified centers of the brain responsible for wants and urges for muscular movement. Models elaborated herein differentiate between wants, desires, urges and cravings. The WANT model (Wants and Aversions for Neuromuscular Tasks) conceptualizes desires for movement and rest as varying by magnitude, approach or avoidance-orientation (wants versus aversions) and as occupying independent dimensions instead of opposite ends of the same axis. For instance, one hypothetically might be in a state of both high desire for movement and rest simultaneously. Variations in motivation states to move and rest may also be associated with various stress states, like freezing or fight and flight. The first validated instrument to measure feelings of desire/want for movement and rest, the CRAVE

Scale (Cravings for Rest and Volitional Energy Expenditure) is already shedding light on the nature of these states. With these advances in theory, conceptual modeling and instrumentation, future investigations may explore the effects of desires and urges for movement and sedentary behavior in earnest.

**Keywords: urge for movement, desire, physical activity, exercise, motivation, sedentary activity, motivation states, conceptual analysis**

## INTRODUCTION

The question of what motivates human movement, physical activity and sedentary behavior can trace its origin back to the time of the ancient Greeks. Aristotle was of the conviction that movement was the outcome of two faculties working together, practical reason and *desire* (Frijda, 2016; Shields, 2016; Nascimento, 2017). When weighing the contribution of each, he concludes that the "mind is not of itself sufficient to engender motion, but instead relies upon appetite" (Shields, 2016). Furthermore, he refines the roles of desire by stating its main function is to jumpstart movement. He states succinctly, "It is manifest, therefore, that what is called desire is the sort of faculty in the [mind] which initiates movement" (Shields, 2016). In other words, it is desire that actually "prick[s] practical intellect" and sets muscular movement in motion (Shields, 2016). Aristotle's focus, therefore, was on the interaction of affective and cognitive factors to produce movement in the present moment.

In the last century, however, the emphasis has been on trying to understand the individual's stable disposition for physical activity or exercise and promoting these behaviors on the time frame of the week, month or longer. Exercise behavior has typically been studied within the scope of several frameworks, including the mechanistic, social cognitive, socioecological, and humanistic/organismic paradigms (Rhodes et al., 2019). These later traditions are mainly rooted in cognitive-based perspectives which likely exaggerate the "capacity and willingness [of humans] to make rational decisions in order to achieve desired goals" (Brand and Ekkekakis, 2018). They tend to underplay or ignore affective factors, even though these are tantamount for the initiation and refinement of much of human behavior (Frijda, 2010; Ridderinkhof, 2017). For instance, only a few of these theories have considered the idea of desire or similar concepts. An exception seems to be Self-Determination Theory, (SDT), in which intrinsic motivation largely overlaps with craving/desire (Williams and Evans, 2014), and a lack of desire is a central feature of amotivation (Rhodes et al., 2019). Interventions based on cognitive constructs typically have low impact, as gauged by small effect sizes (Ekkekakis and Zenko, 2016), and they have "modest utility as mechanisms of behavior change" (Williams et al., 2019).

More recently, models have emerged that incorporate both conscious and unconscious, affective and deliberative factors affecting muscular movement in the present moment. Dual process theories, such as the Affect and Health Behavior Framework (AHBF), clearly articulate the role of desires and cravings in instigating various health behaviors, such as exercise and smoking (Williams and Evans, 2014; Williams et al., 2019). This model also highlights the central role of hedonic motivation. Williams and Evans (2014) state, "people typically crave/desire what they previously had a positive response to." The central role of cravings in the formation and maintenance of "habit loops" has been the focus of a New York Times best-selling book (Atomic Habits) (Clear, 2018). Nevertheless, no formal theories exclusive to the domain of physical activity highlight the role of desires or urges for muscular movement (Brand and Ekkekakis, 2018; Rhodes et al., 2019; Williams et al., 2019).

Among those specific to movement, perhaps the theories most aligned with the idea of desires and urges are the Affective-Reflective Theory (ART) (Brand and Ekkekakis, 2018) and the model from Conroy and Berry (2017). Both of these models exist within the dual process framework and attempt to balance cognitive and affective processes to explain physical activity, and more specifically, exercise, at the moment activity is initiated (Brand and Ekkekakis, 2018). A relevant construct within both theories is the concept of the *action impulse*, which is the direct intermediary between automatic affective processes and movement behavior. These models do not specify, however, if impulses are conscious and felt. In motor control, the idea of desires for movement has been formally articulated as "wants," which emanate from the inferior parietal lobule of the brain (Desmurget and Sirigu, 2012). In medicine, the concept of restless "urges" has been studied for decades (Garcia-Borreguero et al., 2011). The concept of "appetence" (i.e., strong and provoking desires for movement) has shed light on mechanisms of addiction (Ferreira et al., 2006). In musicology, the concept of "groove" describes the ability of music to generate feelings of urge to move (Matthews et al., 2019). There appears to be considerable overlap in the concepts of desires, wants, urges and related constructs, yet they seem to vary by the dimensions of magnitude, specificity to movement behavior, whether the desire is conscious and felt, as well as valence. However, all these concepts might commonly be characterized as *affectively-charged motivation states* (Kavanagh et al., 2005) *and associated feelings that signal a pressing need to approach or avoid a state of muscular movement (or, conversely a state of rest)*.

At this time, no previous analysis or review has attempted to evaluate, synthesize and expand on these motivation states, despite their prevalence in several intersecting literatures (Aristotle; Libet et al., 1983; Hausenblas and Downs, 2002; Gernigon et al., 2004; Reiss, 2004; Ferreira et al., 2006; Desmurget and Sirigu, 2012; Williams and Evans, 2014; Brand and Ekkekakis, 2018; Rhodes et al., 2019). In fact, most of the research on physical activity and cravings/desires investigates the efficacy of exercise to thwart cravings for other maladaptive behaviors, such as cigarette smoking or alcohol consumption (Ussher et al., 2008). Therefore, the objectives of this conceptual analysis are the following. (1) To describe the theoretical basis of desire as a primary motive of movement as well as sedentary behavior. (2) To provide evidence that such desires/urges exist and may be felt consciously. (3) To clarify terminology and the overlap between desires, urges, and cravings for movement. (4) Lastly, we aim to model relevant situations and emotion states associated with fluctuations in desires to move and rest and move/rest interactions. This paper is not intended to describe a multi-factor model of desires for rest/movement, such as ART or AHBF, but to more clearly highlight the important role of desires as they currently fit in established models (e.g., AHBF) or how they might naturally be included in similar models (e.g., ART). We also do not aim to describe in detail interactions between desires/urges and other factors relevant in active behaviors, such as goals, intentions and other cognitive-related constructs, which is beyond the scope of this current analysis.

# DISCUSSION

## Drives, Tension, Reinforcement, and Reward

### Hull and Drive Reduction Theory

Early studies of motivation conceptualized behavior as a function of instincts, drives, needs and tensions (Reiss, 2004) [see Ford (1992) for a review]. McDougall (1933) was instrumental in defining instinct as a function of "native human propensities" interacting with motor and cognitive "native abilities." When propensities are stimulated by the environment they result in "an active tendency, a striving, an impulse, or drive toward some goal." In Drive Reduction Theory, Hull (1943) described drives (energizers) as arising from innate physiological needs, such as the needs for water, food, air, and sexual activity. Physiological deprivation of these needs results in hunger, thirst, etc. and associated subjective feelings of tension (e.g., being hungry and thirsty). These felt tensions push those affected into action, and the amount of drive is proportional to the intensity of the resulting effort to satisfy the need. Drive reduction theory has poor performance in explaining complex human behavior, such as why humans willingly engage in strenuous and exploratory behavior that does not directly satisfy simple physiological needs (e.g., climb mountains). Drive reduction theory also includes a description of secondary drives, such as the drive for earning money, which are learned through conditioning (Weiner, 1982).

### Kurt Lewin– The Dynamic Field, Tensions and Satiation

The work of Kurt Lewin and his contemporaries provided an important basis for the study of desires and urges. Lewin simply thought of human behavior as an interaction of the person with their environment, varying by the place of the person in an inner "life space" or dynamic field (Lewin, 1951; Marrow et al., 1969; Brand and Ekkekakis, 2018). This field incorporates a constellation of various needs, goals and motives - all changing with the situation – even on a moment by moment basis. In his Force Field analysis, driving and restraining forces act on a person to change behavior by propelling "locomotion" through a psychological field or environment, thus achieving an equilibrium. Lewin also described what he called "psychic tensions" in this field, which are "states of readiness or preparation for action" (Marrow et al., 1969) – not undesirable stress or strain. These emerge in response to a need, want or some other stimulus, manifest as "intention or desire" to carry out a specific task and are "released" when that task is completed (Marrow et al., 1969; Ridderinkhof, 2017). Less recognized is Lewin's work on satiation of tensions with his protege, Anitra Karsten. She observed that desire to complete various movement tasks was indeed related to tension, and as a movement was repeated the tension dissipated and desire diminished - a state of satiation resulting in the behavior ending (Karsten, 1928). If the movement was forced to continue, the participant developed a great aversion to the task. Lewin saw this as a transition from psychological hunger to satiation to "oversaturation" and even related it to burnout – an "exhaustion of the will to work" (Lewin, 1928/2009; Soff, 2012). Importantly, satiation following constant repetition of a task was not due to muscular fatigue but simply a lack of desire.

### Hedonic Pleasure and Reward

From a simple behaviorist perspective, the key to motivation is reward (Skinner, 1938; Skinner and Morse, 1958; Niv, 2007; Williams and Evans, 2014). In short, actions are repeated when reinforced – regardless as to whether this reinforcement occurs internally or from outside of the individual. There are two primary means of reward: positive reinforcement (providing a pleasurable stimulus) and negative reinforcement (taking away a negative stimulus). The strongest rewards follow those behaviors that result in both forms of reinforcement (Skinner, 1938). While the concept of the current study concerns human perceptions and behaviors, it is easier to demonstrate principles of reward with rodents. Imagine a rat who has been denied nourishment and is growing hungry. Providing it with highly palatable food will reduce the pangs of physical deprivation, which is negative reinforcement (Loewenstein, 1996; Tiggemann and Kemps, 2005). This food also provides an immediate positive reinforcement as it stimulates sensory responses that activate neural pleasure centers. If the food was acquired by pressing a lever (a muscular movement) this behavior will be highly reinforced (Skinner, 1938). Consequently, the rodent will continue to press the lever many times. Under conditions of severe hunger, this rodent will be motivated to contract its musculature with greater intensity (Salamone and Correa, 2002; Scheurink et al., 2010) in the effort to counter the aversive stimulus of hunger and in anticipation of a pleasurable reward. Such principles apply to humans as well. In neuroeconomics, the strength, persistence and vigor of muscular movements is considered a key predictor of what individuals value, find rewarding and prefer in their everyday choices (Shadmehr and Ahmed, 2020).

However, pressing a lever, like any type of physical activity, cannot be repeated indefinitely (Niv, 2007). The metabolic cost of movement (e.g., lactate) eventually sets in, resulting in painful and punishing sensations (O'Connor and Cook, 1999; Ekkekakis, 2013; Stults-Kolehmainen et al., 2016). Indeed, with growing fatigue, the punishment of movement becomes more aversive than hunger. Hence, movement is stopped, and rest occurs, which is yet another example of negative reinforcement as the cessation of muscular movement removes the negative stimulus. In this illustration, movement is merely instrumental (Salamone and Correa, 2002; Reiss, 2004); it is completed to acquire an outside source of reward (food) and remove hunger while avoiding excessive fatigue. Thus, from a behaviorist perspective, movement *itself* is not the source of pleasurable sensations, but it may be a source of considerable aversive sensations.

Is it possible that the act of movement itself may result in positive reinforcement? Many species will run purely for the sake of moving (Skinner and Morse, 1958; Garland et al., 2011; Roberts et al., 2012) and will even press a bar repeatedly to gain access to a running wheel (Collier and Hirsch, 1971; Belke and Pierce, 2014). However, it is debatable whether movement itself is naturally reinforcing in humans (Schultheiss and Wirth, 2008; Garland et al., 2011). Based on their empirical evidence, Cacioppo et al. (1993), Cabanac (2006a,b), and others (e.g., Schultheiss and Wirth, 2008) have argued that muscular movement must be reinforcing because it is the primary method of acquisition and consumption of many pleasurable stimuli, repeated many times over one's life. In short, where movement is useful it must also be pleasant and wanted, at least occasionally. Furthermore, some human behaviors are fundamentally motivated even when there is no specific reward associated with them, such as exploration, perhaps because of the occasional discovery of a pleasurable, unconditioned stimulus (Schultheiss and Wirth, 2008). The extent to which these arguments are valid in a modern world, where machines can do both our labor and exploration, is uncertain. Nevertheless, it is generally accepted that voluntary physical activity may be agreeable (Garland et al., 2011; Boecker and Dishman, 2013), and there is an abundance of observations that some individuals even frolic, particularly children (Panksepp, 2006). That is, they move with joy and exuberance (Frijda, 1987; Panksepp, 2006).

In regards to structured exercise, the largest body of human research has centered on the potential of exercise to provide both immediate (mood and enjoyment) and delayed (body image) positive reinforcements, both directly and indirectly (e.g., social interactions) (Ekkekakis, 2013). Exercise increases vigor and feelings of positive well-being in both normal and clinical populations (Bartholomew et al., 2005). The phenomenon of a "runner's high," a state of euphoria during or following endurance exercise, is linked to opioid binding in prefrontal/orbitofrontal cortices of the brain (Dietrich and McDaniel, 2004; Boecker and Dishman, 2013). Exercise of almost any modality provides enhancements in affective tone, particularly during moderate intensity exercise and in the rebound period after strenuous exercise (Ekkekakis et al., 2011; Ekkekakis, 2013). Variability in feelings of pleasure during exercise (but not afterward) is a predictor of adherence to exercise programming (Williams et al., 2008; Rhodes and Kates, 2015), which seems to indicate that for some individuals, physical activity is rewarding and reinforcing for future behavior. Some individuals even "like it vigorous," in other words, prefer a high level of intensity for their exercise (Ekkekakis et al., 2005) and find meaning and pleasure in the face of displeasure. Collectively, enjoyment, intrinsic motivation and affective attitudes about exercise appear to be key mediators in the relationship between affective responses to exercise and future activity behavior (Rhodes and Kates, 2015).

## Physical Activity as a Negative Reinforcer

Movement is motivated not only by the optimization of pleasure, but by reducing displeasure (Cabanac, 2006a). What is lacking in the extant literature, however, is a thorough consideration of physical activity as a negative reinforcer – that movement may serve to alleviate tension (Williams and Evans, 2014). Some research exists concerning the relief of negative affective states (i.e., poor mood and distress) (Salmon, 2001; Stults-Kolehmainen and Sinha, 2014) and reduction in pain sensation (e.g., exercise-induced analgesia) (Bartholomew et al., 1996). However, these mood states have largely been considered as arising from an external source (e.g., work stress, social anxiety, etc.). That is, the activity itself is not tied to the *source* of negative mood. In these cases, exercise is no more or less effective than other means to improve mood (Thayer et al., 1994). As such, exercise is a choice no more compelling than relaxation practices, alcohol use, distraction (e.g., TV), and other forms of stress coping (Ingledew et al., 1996; Endrighi et al., 2016).

However, might it be that some of these negative states may be derived from the *lack* of physical activity? That is, could there be a drive for physical activity that requires some degree of activity to satisfy the need (Collier, 1970; Feige, 1976; Reiss, 2004; Schultheiss and Wirth, 2008; de Geus and de Moor, 2011; Kalupahana et al., 2011)? One might propose that all humans are "hard wired" for movement for: (a) instrumental reasons (e.g., foraging for food, seeking and building shelter, etc.), (b) for play, which helps to develop physical traits, develop social skills and improve affective tone (Panksepp, 2006), (c) for seeking out rewards, novel stimuli and new experiences (Schultheiss and Wirth, 2008; Panksepp and Biven, 2012; Frijda, 2016), (d) for acquisition and processing of information (Parker et al., 2020) and other reasons (Cabanac, 2006a,b). Aristotle concluded that desires to move and rest are the drivers which "prick" these behaviors in the moments before they are initiated (Aristotle; Shields, 2016; Nascimento, 2017). Other early literature [summarized by Ekkekakis (2013)] noted that humans have an "inherent propensity" or "drive for activity," a need for stimulation or "susceptibility." Many people even prefer electric shocks over total solitude (Wilson et al., 2014). More pertinently, these drives are *felt* as a "necessity of body exercise," "volitional promptings" (Bain, 1855; Baldwin, 1891, 1894; Shirley, 1929; Hill, 1956; Finger and Mook, 1971) or tension, perhaps similar to appetite (Loewenstein, 1996; Rowland, 1998; Ferreira et al., 2006). Particularly under restrained conditions (i.e., prolonged sitting) humans feel "intense uneasiness or craving" or "pressing readiness." Over 100 years ago, Williams James related the case of a girl that had a "morbid impulse" causing her to "walk, walk, walk" (James, 1907).

Almost anyone can identify with the discomfort of sitting for prolonged periods, feelings of being antsy, jittery, squirmy, restless and/or fidgety, and the relief provided by movement (Levine et al., 2005). Several slang terms are also associated with similar conditions and feelings, including being "cooped up," "stir crazy," or having "cabin fever." Those with low back pain disorders fidget and shift their bodies, sometimes multiple times every minute, in order to relieve pressure and avoid pain (Dunk and Callaghan, 2010). However, systematic evidence for these behaviors are lacking in the current human literature. In research in the post-behaviorism era, such aversive sensations are generally linked to a limited number of phenomena, including urges associated with Restless Leg Syndrome (Garcia-Borreguero et al., 2011), akathisia (characterized by a compelling need to be in constant motion) (Iqbal et al., 2007), hyperactivity (Willerman, 1973; Scheurink et al., 2010), anorexia (Davis and Woodside, 2002; Scheurink et al., 2010), forced bed rest (Ishizaki et al., 2002), loss of playtime/recess (Jarrett et al., 1998), sudden decline in one's usual exercise routine (Mondin et al., 1996), and exercise dependence/addiction (Hausenblas and Downs, 2002; Ferreira et al., 2006). Consequently, urges to move are well-documented in situations where such sensations are bothersome and unproductive.

### Processes of Wanting

An alternative framework for understanding wants/desires for physical activity and rest is the incentive sensitization model (ISM) of rewarding behaviors (Robinson and Berridge, 1993; Berridge and Robinson, 1998; Roemmich et al., 2008; Boecker and Dishman, 2013). For any given pleasurable stimulus, the ISM proposes that there is both a hedonic *like* and an appetitive (motivational) *want* (Smith and Berridge, 2007), which vary in intensity from transient desires to cravings or urges. Likes and wants are typically tightly linked (as in the case of food or drugs), but these constructs differ in several important ways. First, there is evidence that they are controlled by different neurobiological systems – opiod for likes and dopaminergic for wants (Roemmich et al., 2008; Boecker and Dishman, 2013). Furthermore, *likes* and *wants* may become completely uncoupled, whereas in certain situations one may want to perform a particular behavior without necessarily liking it. For physical activity, this is most clearly relevant in the case of exercise dependence/addiction, in which individuals feel compelled to engage in physical activity even when it comes at great costs and is not enjoyable (Hausenblas and Downs, 2002; Ferreira et al., 2006).

The ISM also describes processes of wanting, including the prediction of when wants and desires may be whetted (stimulated), consummated and satiated. Wants are triggered by salient cues (irrespective of rewards), such as interoceptive sensations of tension, which may be amplified under conditions of physiological deprivation. In the case of physical activity, an example might be prolonged periods of unaccustomed sitting. Cues may also activate mental networks of associations (memory) to elicit urges (Rhodes et al., 2019). Furthermore, individuals become more sensitive to a reinforcing stimulus as it is repeated, causing the stimulus to be more salient and more attractive, leading to *wanting* the stimulus more. Flack et al. (2019a,b) have investigated exercise protocols lasting 3 months under this paradigm, and found that more frequent exercise, or exercise with more total volume (i.e., 300 kcal/day, 5 days/week) can increase the relative reinforcing value of exercise compared to sedentary activities in a group of untrained and overweight individuals. It is unknown if physical activity, outside of exercise, can become more rewarding and salient with repeated exposure, particularly for those who are typically inactive.

The ISM model has several drawbacks. First, it was developed in examination of rewarding substances like food or drugs. However, physical activity may differ from these substances in that: (a) the latter emanate from external sources, (b) consumption is highly tied, at least initially, to the experience of pleasure, while physical activity may not be, (c) they are subject to scarcity while movement typically is not and (d) movement is required for the acquisition of the former. Moreover, given the great utility of movement, it must be accomplished in day-to-day life, and thus is likely wanted, even if is not necessarily liked (Cabanac, 2006a,b). Consequently, liking and wanting of physical activity may be loosely coupled for most of the population. Lastly, this model underplays the role of affect, which is discordant from the well-established literature describing relationships between movement and emotion (Stults-Kolehmainen and Sinha, 2014; Ridderinkhof, 2017; Williams et al., 2019). Despite these downsides, the ISM model is valuable in emphasizing the importance of craving as an intermediary state prior to action, representing motivation and intent.

## Self-Determination Theory

In the view of Roberts (2012), the aforementioned theories of drive and behaviorism are "deterministic and mechanistic," which "view humans as being passive." Organismic theories, like Self-Determination Theory (SDT), and more specifically, the sub-theory of organismic integration theory, integrate and expand on the concept of human needs and drives, consider the person's goals and feelings and evaluate the person in a social context (Deci and Ryan, 2000). The three basic psychological needs are competence, autonomy, and sense of relatedness. However, Deci and Ryan (1985) state that self-determination itself is the "capacity or fundamental need to choose and to have choices, rather than reinforcement contingencies, drives, or any other forces or pressures be the determinants of one's actions." People who are self-determined act upon fully internalized motivations, categorized into three distinct drives: intrinsic motivation to know, to accomplish and to experience stimulation (Vallerand et al., 1989; Vallerand, 1997). Performing movement for its own sake and for its enjoyment is considered intrinsic motivation (Reiss, 2004; Rhodes et al., 2019). Moreover, intrinsic motives can exert a powerful and long-lasting influence on exercise behaviors (Teixeira et al., 2012). Williams and Evans (2014) explicitly distinguish between sources of motivation (e.g., to experience stimulation) versus the affective charge attached to a motivation state. They conclude that, "intrinsic motivation is typically an affectively-charged motivation state that involves either craving/desire or fear"; however, they also recognize that movement is accomplished in the absence of strong desire. According to SDT, behavior is also influenced by extrinsic motives, such as tangible rewards (e.g., trophies), or wanting to be someone specific (e.g., a highly competitive athlete), which are farther down on the continuum of self-determination. Nevertheless, these also can result in strong desires, as in the case of having a strong, affectively-charged desire to perform sport because it is expected to result in strong social approval and the admiration of others (Williams and Evans, 2014). Ostensibly, one might have multiples desires at the same time, such as a desire for a reward (extrinsic) and a desire for movement itself (intrinsic). In this case, however, movement might be merely instrumental and secondary to the more pressing desire (Reiss, 2004). Amotivation, on the other hand, is a state of no motivation, or a near-total lack of desire or drive to perform a behavior. Consequently, SDT appears to be a complimentary theory, likely concordant with the idea of wants or urges for movement, that could be gleaned for information on how to broaden and categorize these desires.

## Dual Process Theories

### Affect and Health Behavior Framework (AHBF)

The AHBF (Williams and Evans, 2014) outlines a dual process model in which learned automatic (unconscious) associations (A-system) and reflective/deliberative processes (R-system) work in concert to propel health-related behavior (Strack and Deutsch, 2004). In this model, "wanting" is considered *automatic motivation* as part of the A-system, along with the opposite construct, *dread.* Dread is a concept related to the emotion of fear – a motivational force that propels a person to move away from or avoid an aversive stimulus (Kringelbach and Kent, 2016). Williams and Evans (2014) distinguish these from desires, cravings and fear, which they label as *affectively-charged motivation* (Kavanagh et al., 2005). These are the product of conflict between automatic impulses (e.g., wanting and dread) and reflective intentions and goals (R-system) (Williams and Evans, 2014). Despite these divisions between desire, craving and wanting in their model, the authors seem to also categorize the former two as part of wanting and all of these, together with dread and fear, as part of affectively-charged motivation states (ACMS).

The model provides an understanding, though incomplete, of how an individual might have motivation states for physical activity. They note that, "people typically crave/desire what they previously had a positive affective response to," which would seem to include physical activity. However, they later explain that these factors are typically only implicated with the experience of highly palatable food, sex, drugs, etc. (Williams and Evans, 2014). Physical activity is not considered a source of cravings/desire, but rather it is largely seen as a source of dread. In the example they provide, exercise is frequently and automatically associated with fatigue and pain, thus resulting in aversion as the automatic motivation. This restraining force may come into conflict, however, with a long-term intention of going outside to run. Whether an exercise action prevails is also influenced by competing behaviors (e.g., watching TV) and one's current mood state and mental stress (Stults-Kolehmainen and Sinha, 2014). Despite some lack of clarity in this model, it provides an important advancement in the exploration of desires and cravings in physical activity research.

Williams et al. (2019) later revamped and extended the AHBF in their integrated framework (IF or AHBF-IF). Several improvements are observed in this model. First, it more clearly structures the relationships of all included factors, with paths starting with affect proper (specific mood and emotions), leading to motivation states and ending with behavior. It highlights the role that incidental affect can have on physical activity behavior (Lutz et al., 2010). Second, they collectively categorize wanting, desire, dread and aversion, so as to avoid the arbitrary divisions between these factors seen in the previous model. However, they relabel them as "hedonic motivation" as opposed to affectively-charged motivation states. A third strength of this revised model is that one can clearly delineate both the antecedents of affectively-charged motivation states (e.g., desires/urges) as well as their influence on behavior. Affectively-charged motivation states are seen in this model as proximally mediating the relationship between *affect processing* and behavior. As with other models discussed below, there is both an automatic and a reflective pathway, with affective processing and motivational processes occurring in both paths. Thus, the model supports goal-directed and purposeful motivation. Based on these improvements, more testable hypotheses may be formulated, and it is easier to generate examples of how desires might work in the real world. For instance, experiences of post-exercise affect (e.g., post-run euphoria) could result in an automatic association of running with pleasure. Anticipating this response again could lead to desires to run at another opportunity. On the other hand, the experience of inordinate work stress (incidental affect), resulting in poor mood, might activate automatic associations of exercise and excessive fatigue, resulting in an aversion to exercise, which squelches physical activity (Stults-Kolehmainen and Sinha, 2014). Overall, the AHBF-IF is an improved multi-factor model explaining how desires/urges may be generated and result in some movement behaviors – i.e., exercise.

Despite improvements, the AHBF-IF still has several limitations. A continued drawback with this model is that it is not specific to physical activity but generalized to all intentional health behaviors (e.g., smoking). Also, when considering physical activity, the models primarily seek to explain purposeful, structured exercise behavior, and it's not clear if the model can explain the greater spectrum of physically active behaviors (i.e., task-specific movement, spontaneous movement, fidgeting). More significantly, cravings or desires *specifically for movement* are not considered in this model even though it opens the possibility that these exist. Because of the simplification and recategorization of affectively-charged motivation states ("hedonic motivation"), there remains ambiguity in the interaction between desires and dread for exercise behaviors. Furthermore, the model lacks a clear articulation on the role of restraining forces, such as the need or urge for rest and how these conflicts occur in the moment (Frijda, 2010). Finally, the model does not provide an explanation for how affectively-charged motivation states, such as desires, interact with goals and intentions.

### Affective-Reflective Theory of Physical Inactivity and Exercise (ART)

Several recent dual process models have focused specifically on exercise behavior, such as the Affective Reflective Theory of physical inactivity and exercise (ART) from Brand and Ekkekakis (2018) and a similar model from Conroy and Berry (2017). These authors similarly hypothesize that movement is the product of the interplay between two systems: a type-1 automatic process and a type-2 process for reflective valuation (Conroy and Berry, 2017; Brand and Ekkekakis, 2018). They describe the conflict between an actual state and "desired state" (i.e., exercising) due to driving forces and restraining forces, as similar to the concept of tension systems from Lewin (1951). In their model, an exercise stimulus elicits a spontaneous affective response (i.e., pleasure/displeasure associated with the activity) through type-1 processing, resulting in an action impulse. Following this, slower type-2 processing is used to reflectively generate an action plan. The combination of the type-1 action impulse and type-2 action plan results in physical activity behavior. However, discordance can exist between the action impulse and the action plan. An example of this would be when a seated individual is exposed to an exercise stimulus (e.g., sees a person running), and immediately associates it with an aversive state (e.g., running is tiring – which is bad), which prompts the individual to remain sedentary. At this time, however, the individual also thinks about her/his doctor's advice to exercise more frequently. In this case, Brand and Ekkekakis (2018) propose that the behavior that will follow depends on the availability of self-control resources, where a greater availability will result in the execution of the action plan (i.e., go exercise) instead of the action impulse to be sedentary.

There are limitations with the models from Brand and Ekkekakis (2018) and Conroy and Berry (2017). The first is that the concept of the action impulse is poorly defined, but seems to relate to a variety of other concepts, including: (a) Lewin's description of psychic tension (Marrow et al., 1969), (b) the "prick" that was described by Aristotle (Aristotle; Shields, 2016; Nascimento, 2017), (c) the concept of "wants" as defined in motor control (Libet et al., 1983; Desmurget and Sirigu, 2012) or (d) it may be interchangeable with the concepts of *states of action readiness (SOAR), action tendency* (McDougall, 1933; Frijda, 1987; Frijda et al., 1989; Strack and Deutsch, 2004), *activation states* or a "specific motive state" in the description of *impulsive action* (Frijda et al., 1989, 2014; Frijda, 2010; Frijda, 2016). Nevertheless, the authors note that, "core affective valence may have a direct, immediate impact on behavior through behavioral urges" (Brand and Ekkekakis, 2018). The second problem is that this theory was created to explain the complex behaviors of exercise and regimented physical activities – as opposed to the greater spectrum of physically active behaviors, including spontaneous physical activity (Levine et al., 2005). The third issue is that the model represents sedentary behaviors as typically contrasting with physical activity; restraining forces pulling against propelling forces to alternate from one behavior to the other (e.g., flipping a single switch). However, rest and activity may not be in direct opposition. Instead, there may be restraining and propelling forces for both rest and movement acting simultaneously (e.g., two separate switches, or even two dials) (Beeler et al., 2012; Stults-Kolehmainen et al., 2020). The practical consequence of these limitations relates to intervening for muscular movement at the moment actions are being processed and how this might be modified or done flexibly based on desires for rest as well. Indeed, the purpose of these dual urges, working in concert, may be to "potentiate sets of action schemas with equifinality" for adaptive behavioral flexibility (Frijda, 2010).

## Dynamical Model of Desire and Elaborate Intrusion Theory

Alternative multi-process models specifically highlight the powerful influences of wants/desires on human behavior. Hofmann and Van Dillen (2012) and Hofmann et al. (2012a,b) in their Dynamical Model of Desire draw on a diverse literature, defining desire as "a psychological state of motivation for a specific stimulus or experience that is anticipated to be rewarding [which] may or may not be consciously experienced" (Papies and Barsalou, 2015). This model also defines two routes by which desires can influence behavior: (a) an automatic, impulsive and unconscious route and (b) a route in which desires emerge into consciousness, become felt (e.g., have a subjective sense of wanting/feeling wants), interact with working memory and "hijack" cognitive processing. In the view of Kavanagh et al. (2005) in their Elaborated Intrusion Theory desire is "an affectively-charged cognitive event in which an object or activity that is associated with pleasure or relief of discomfort is in focal attention. . .it can be referred to as a conscious wish or urge to gain pleasure, relieve discomfort, or satisfy a want or to engage in consummatory behavior associated with these outcomes." In this model, desire inherently involves cognitive processing and is often instigated by triggers (i.e., thoughts, cues, affect, and physical needs) that result in spontaneous, conscious and intrusive thoughts. Regardless of the definition or the specific factors in play, Hofmann et al. (2012a) have found that over 50% of a person's waking hours are filled with various desires (Hofmann and Van Dillen, 2012). The most common desire is that for sleep, but desires abound for many rewarding stimuli: coffee, leisure, sex, and numerous other activities and objects (Hofmann et al., 2012b). Desire for muscular exertion is considered to be one of the most fundamental desires (Reiss, 2004). Unfortunately, only cravings for participation in sport activities has been systematically investigated (May et al., 2008; Hofmann et al., 2012a,b). In one exception, Katula et al. (2006) investigated the desire to be stronger and increase fitness. In this study, it was found that adding an empowering psychological intervention to a traditional strength training protocol increased the desire to gain strength in older adults.

## Important Contributions From Motor Control

Up to this point, there has been little clarity on the issue of "action impulse" or "action readiness" and how they relate to the initiation of and wants for movement. Research in motor control appears to address this gap most adequately by investigating wants (e.g., often referred to as "intentions") and urges at the level of simple movements (e.g., standing up, moving a finger). This work began with Libet et al. (1983), who asked participants to remember the moment they became aware of their want to move. This study was ground-breaking at the time because the data demonstrated that individuals' neural preparation for movement (i.e., readiness potential) occurred before they became consciously aware of their want/intention to move. Matsuhashi and Hallett (2008) improved on flaws in Libet's original study design and found that the intention to move goes through multiple layers of awareness and enters consciousness 1.42 s prior to actual movement initiation. The authors also found evidence of a "point of no return," which occurs when the want/intention to move cannot be vetoed- an urge. Wants for movement have a neurophysiological basis and seem to originate in the supplementary motor cortex (SMA), pre-SMA, posterior parietal cortex (PPC), pre-motor area, motor cortex, intraparietal sulcus, and in the insular cortex (Lau et al., 2004; Fried et al., 2011; Desmurget and Sirigu, 2012; Li et al., 2015). Neuronal activity in the SMA precedes the conscious awareness of wanting/intention to move by 700 ms and predicts it with 80% accuracy (Fried et al., 2011). Furthermore, Desmurget and Sirigu (2012) found that the inferior parietal lobule is responsible for the preparatory "wanting to move," while the mesial precentral area is responsible for the more powerful "urge to move.". Collectively, the readiness potential and/or the conscious awareness of wanting to move might be referred to as the "action impulse."

## Defining, Categorizing and Describing Desires/Urges to Move and Rest

Based on a multitude of evidence, it is apparent at this juncture that desires/cravings for movement exist, but progress is still impeded by a lack of conceptual organization and instrumentation. The first issue is the abundance of related, yet distinctive, terminology – including the nomenclature above but also terms from Frijda and colleagues work on states of action readiness (SOAR), such as motor intention, longing, striving, "current concerns," action tendency, urgency, control precedence, awareness of action readiness and "non-overt inclination" (Klinger, 1987; Strack and Deutsch, 2004; Pacherie, 2005; Elster, 2009; Frijda et al., 2014; Frijda, 2016; Ridderinkhof, 2017). Part of the confusion seems to stem from considerations of motivations states [e.g., urgency (Elster, 2009)], processes [e.g., "wanting," (Berridge and Robinson, 1998)] and distinct, concrete felt perceptions and other unfelt forces (*a* "want", *an* "urge"). To tackle this issue, the concepts of wants, desires, appetence, groove and the action impulse (i.e., action readiness) were all plotted on a field distinguishing them by apparent differences in valence (negative or positive tension) and their specificity to movement (see **Figure 1**). The concept of groove, for instance, is specific to a felt need to move, and is ostensibly conceived as a positive force or tension (Matthews et al., 2019). It is highly contextual to the influence of music, however. Urges to move, most cited in work on Restless Legs Syndrome, are highly specific in this context to muscular movement but are clearly gauged as a negative tension. Patients with Restless Leg Syndrome, other variants such as Restless Arm or Mouth Syndrome, and Tourette's Syndrome report pressing, involuntary and bothersome urges to move and/or stretch that are often temporarily suppressed but eventually released (Cavanna and Nani, 2013; Jung et al., 2017; Ruppert, 2019). Appetence is highly specific to movement, but neutral in feeling in the same sense that appetite may be either present or lacking but distinct from the pangs of hunger (Ferreira et al., 2006). Wants have also been highly related to movement in the motor control literature, but usually are considered neutral in valence. Desires, on the other hand, have lacked specificity to movement and rest and have a positive connotation. Finally, it must be considered that constructs such as desire and want, while in this context highly concrete (e.g., they are discrete, observable and measurable) are typically used in a much more abstract and conditional sense (e.g., she wants to go for a walk after work). This makes completing literature reviews in the area difficult because keyword searches result in tens of thousands of irrelevant returns.

As mentioned above, there is a question about how desires/wants to move relate to desires for contrasting behaviors, such as being sedentary or resting. Thus far, the focus has been on motivation states for movement, but special attention is needed to elucidate whether rest-related wants should be conceived as a restraining force acting simply against movement or a separate dimension of wants interacting flexibly with those to move. In his early work, Frijda (Frijda, 1987; Frijda et al., 1989) characterized rest as a state involving an "absence of action readiness," a feeling of not needing to do anything, rather than a separate dimension or system. However, there is reason to believe that rest and movement wants/urges operate in separate planes/continua and are not opposite ends of the same axis. First, as indicated above, other researchers have separated these into distinct desires, asking respondents to report whether they want to sleep, or rest or engage in movement activities (Reiss, 2004; Hofmann et al., 2012a,b). Indeed, sleep likely has its own drive (Hull, 1943). Second, such conceptualization of desires and rest as separate factors was demonstrated by a recent factor analysis (Stults-Kolehmainen et al., 2020). Finally, the idea of separate systems for rest and movement desires seems to be concordant with other similar work describing separate "go" and "no-go" (Beeler et al., 2012) and appetitive versus defensive systems (Frijda, 2010; Lang and Bradley, 2010). Thus, it appears reasonable that one can approach or avoid both desires for rest and movement separately (Frijda, 2010). In other words, rest and movement desires together do not correspond to a unidimensional approach/avoidance for movement.

Conversely, it is proposed that there is approach/avoidance orientation for each system (rest and move) which corresponds to wants and aversions for each action (Cacioppo et al., 1993). These forces, in turn, vary by strength as well. One might consider the concept of dread as being more than the intense lack of urge to be in a state of movement/rest (i.e., a 0-point) but also an *active avoidance* of those states (Williams and Evans, 2014; Kringelbach and Kent, 2016). For instance, those with chronic low back pain and/or kinesiophobia exhibit fear and dread of movement and make attempts to actively avoid it, when possible, to prevent painful sensations (Barke et al., 2012). Consequently, it appears that a dimension of avoidance/approach, each of which varies by magnitude or level of activation/deactivation, is more appropriate than categorizing them by negative/positive valence (Watson et al., 1999; Rosenberg, 2009; Kemps et al., 2013; Williams et al., 2019). Furthermore, wants/desires, while typically affectively-charged, are independent from emotion (Kavanagh et al., 2005; Williams and Evans, 2014; Williams et al., 2019). In contrast, wants/desires appear to often be triggered by and result in various emotion states (Frijda et al., 1989). Regarding

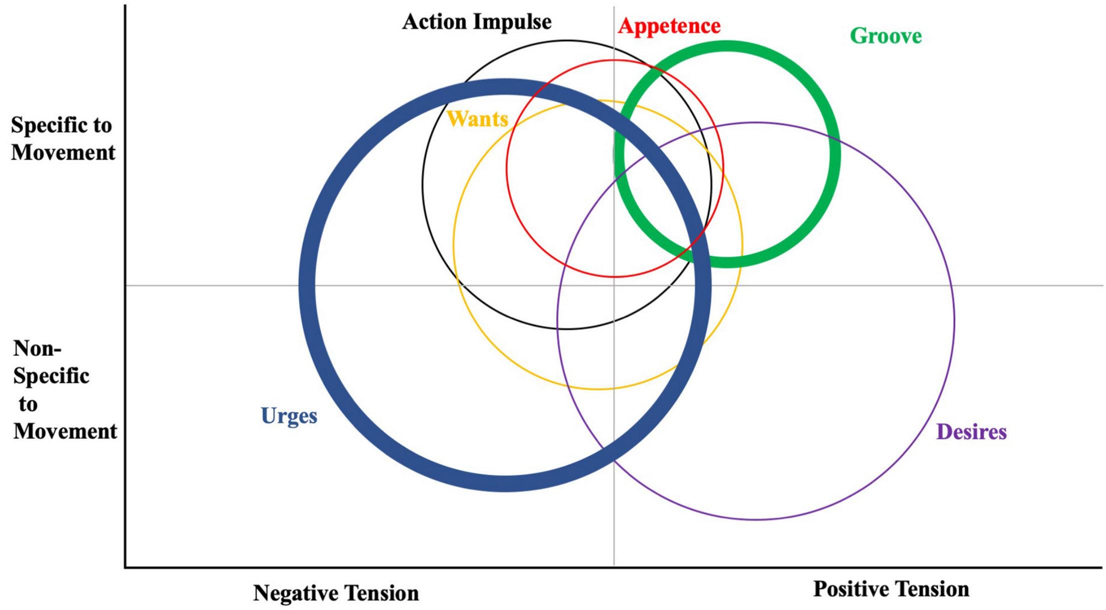


**FIGURE 1 |** Venn diagram illustration of some affectively-charged motivation states (ACMS; urges, wants, appetence, groove, desires, and action impulses) as they vary by specificity to muscular movement and valence of the tension. Some concepts originated with movement (i.e., groove and appetence) while others are generally applicable to a multitude of reinforceable behaviors. Circle size denotes degree to which the state covers multiple quadrants. Thickness of circle line denotes prevalence of theme in current literature. [Not all ACMS constructs are included].

magnitude, desires/wants ostensibly can range from very weak to very strong. In motor control, strong wants are labeled as "urges," and importantly, urges are closer to the actual manifestation of movement than wants (Desmurget and Sirigu, 2012). **Figure 2** provides an intermediary categorization how wants, desires, urges and cravings, the most described motivation states, might be conceptually organized to explain movement and rest behaviors. It explicitly divides move and rest wants/urges into separate categorizations. A substantial shortcoming of the simple categorization of motivation states in **Figure 2** is that it does not consider how desires for rest and movement can interact to produce flexible and adaptive behavior.

## The WANT Model

How desires to move and rest interact might be best visualized in an orthogonal perspective. Given the logic above outlining separate dimensions or systems for move and rest, it's proposed that one might occasionally occupy conditions in which one is high in both desires to move and rest – as well as low in both. The same may be true for avoidance orientation (e.g., high in the need to avoid both movement and rest, i.e., dread) (Jean-Richard-dit-Bressel et al., 2019). **Figure 3** plots the WANT (Wants and Aversions for Neuromuscular Tasks) model. This is a descriptive, circumplex model (Guttman, 1954; Acton and Revelle, 2002) of affectively-charged motivation states (i.e., ACMS; desire, urges, aversions and dread) to move and rest, the continua of which are positioned orthogonally from each other. Importantly, and unlike other models, both desire and dread are modeled on the same continuum as opposed to being separate constructs (Williams and Evans, 2014; Williams et al., 2019).

The WANT model was designed to plot, categorize, and help to describe potential situations in which desires/urges to move/rest may occur, as well as associated emotional phenomena that may be generated in those circumstances. For instance, simultaneously experiencing very high rest and very high move wants/urges might occur in situations, such as: (a) having just won a competition and wanting to celebrate, but also being physically exhausted, (b) being torn between the need to workout or rest/have a meal, (c) suddenly becoming injured in the middle of competition, (d) overtraining, or other situations in which one might feel conflicted. Being low in both move and rest wants/urges, conversely, would be closer to the intercept of these axes, a state of deactivation that might be similar to a state of depression (Frijda, 2016) or possibly a meditative state of mindfulness and stillness. The WANT model also delineates avoidant motivation states characterized by feelings of *not* wanting to rest to move (diswants), in other words, having an aversion or dread. Relevant emotional outcomes in these quadrants include a variety of stressor states, like fight or flight (Frijda et al., 1989). Conversely, one might experience freezing behavior in the face of danger, which might be characterized as motivational states high in dread for both movement and rest (Frijda, 2016). Frijda (2016) argues that in such situations, there is no action readiness and individuals face "motivational null states" because "no meaningful action can be conceived."

The WANT model incorporates several advances. First, it explicitly describes affectively-charged motivation states (ACMS) along several dimensions: (a) move vs. rest axes, (b) approach (desire/urge) vs. avoidance (aversion/dread) orientation and (c) relative strength of desire (inner vs. outer circle symbolizing want

| MOVE | | Wants (mild) | Urges (intense) |
|---|---|---|---|
| | Approach | Desire(s) to move | Craving(s) to move |
| | Avoid | Aversion(s) to move | Dread* to move |

| REST | | Wants (mild) | Urges (intense) |
|---|---|---|---|
| | Approach | Desire(s) to rest | Craving(s) to rest |
| | Avoid | Aversion(s) to rest | Dread* to rest |

**FIGURE 2 |** Want/urge motivation states specific to the domains of movement and inactivity behaviors: Approach/avoidance orientation vs. Intensity. This is a simple categorical model preceding the model described in **Figure 3**. *Singular and plural for impulses of dread (multiple instances of dread).

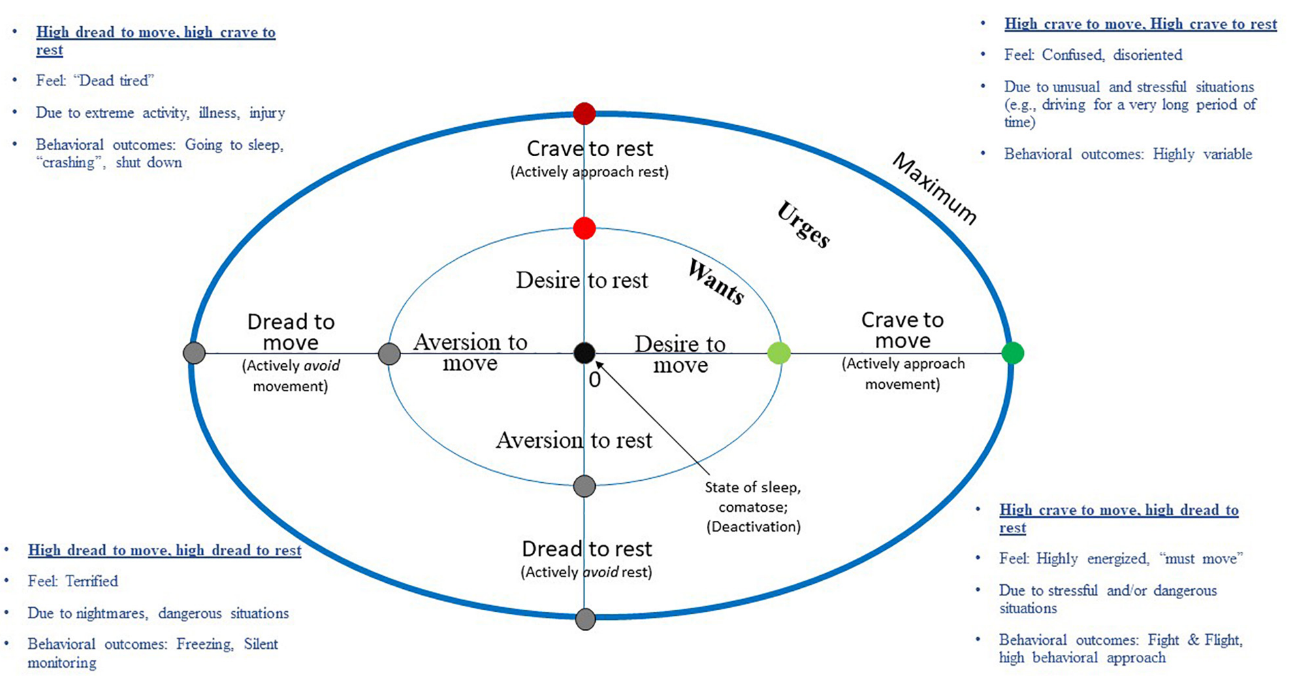


**FIGURE 3 |** Wants and aversions in neuromuscular tasks (WANT) circumplex model of affectively-charged motivation states (ACMS, i.e., wants, urges, aversions, and dread) to move and rest. Interactions between these factors are associated with a variety of situations, emotions, and psychological phenomena.

vs. urge strength) with a 0 point and a hypothetical maximum. This allows the reader to determine relations more easily among variables. There is also predictive value to this taxonomy. As suggestive above, a score high in move and low in rest might be predictive of a highly energized state of action readiness for action. Frijda (1987) describes excitement as "impulse toward restless movement, with frequent changes in direction" and not being able to sit still (Frijda et al., 1989). Likewise, exuberance is "impulse toward enhanced movement scope and movement abundance" with those selecting this emotion reporting, "I wanted to move, be exuberant, sing, jump, undertake things" (Frijda, 1987; Frijda et al., 1989). Therefore, the model permits categorization of various situations, emotions and feelings as described above by quadrant (e.g., high move/low rest; high move/high rest). One can also map transitions, both sudden and gradual, in move/rest desires and placement in "fuzzy" situations (e.g., feeling really tired but also relying on one's body to get home after work) (Guttman, 1954; Acton and Revelle, 2002).

The utility of the WANT model to help formulate testable hypotheses or predict *future* states or behaviors is yet to be determined. How specific desires/urges (or combination of desires) interact with other factors to ultimately drive behavior is not modeled. Pacherie (2005), Frijda et al. (2014), and Frijda (2016) point to the fact that desires and states of action readiness (SOAR) do not absolutely determine behavior. Rather, desires are highly flexible in their behavioral outcome since many different actions can result from the consummation (or not) of desire (Frijda, 2016). Such flexibility is likely advantageous and adaptive. This being said, the relative strength of competing urges plays a part in behavioral choice (Hofmann et al., 2012a,b). Deliberative factors also can act on specific desires to enhance or minimize their impact (Hofmann et al., 2015). Lewin's force field analysis seems to suggest that a multitude of forces work in tandem to help an individual achieve a state of equilibrium (Marrow et al., 1969; Brand and Ekkekakis, 2018), and this varies by a variety of individual needs, motives and situational factors which are beyond the scope of this model to include. From a neuropsychological perspective, how one behaves might primarily be a function of dopamine regulation, as in the "go" and "no go" model (Beeler et al., 2012). While the WANT model is not high in predictive value, it is intended to be helpful for understanding the nature of desires/urges, which is needed before adequate path models can be created.

## Future Research

Research on desires or urges to move and rest is still in formation, and many avenues of research exist to realize its potential. To move forward, the following 10 areas should be considered.

(1) While some progress has been made in defining desires and urges, how they relate to each other, and how they may influence physically active or sedentary behaviors, there are no systematic literature reviews in this area of inquiry.

(2) The fundamental nature and descriptive quality of desires/urges to move still needs clarification. One basic issue relates to conscious awareness of desires/urges to move and how they are experienced or felt (Frijda et al., 1989; Hofmann et al., 2015). Are they felt as positive or negative, intrusive, and/or unwanted? Do they vary from young to old age? How frequently do they occur and how quickly can they change (Gernigon et al., 2004)? Are they more prominent during the acquisition or solidification of physical activity habits (Clear, 2018; Greenwood and Fleshner, 2019)?

(3) The WANT model (**Figure 3**), describing the orthogonal nature of desires to move and rest needs testing and empirical validation (Acton and Revelle, 2002), the beginning of which is described in a recent paper (Stults-Kolehmainen et al., 2020). One drawback is that the model does not explicitly include an additional dimension of affect (e.g., pleasure/displeasure), chronicity (i.e., a single urge versus constant craving), or effect on motor behavior, which may necessitate refinements of the model.

(4) Is there a threshold of want/urge magnitude to initiate movement, as suggested by the motor control research (Desmurget and Sirigu, 2012), and how does this relate to conscious awareness of the desire or urge (Libet et al., 1983)? The definition of "maximum" should also be clarified, whether that is defined psychometrically (e.g., feel "more than ever"), cognitively (i.e., the urge dominates thoughts) or behaviorally (e.g., motor actions have been initiated).

(5) There is an obvious lack of a model, specific to movement and rest, to expound on the antecedents of desire and the varying impact on behavior, which could help to create testable hypotheses for future investigations. Such a model would be best fashioned in light of the multiple disciplines that have a shared interest in desires/urges to move, such as exercise psychology, motor control, clinical medicine and psychiatry (Hausenblas and Downs, 2002; Ferreira et al., 2006; Iqbal et al., 2007; Garcia-Borreguero et al., 2011; Desmurget and Sirigu, 2012; Williams and Evans, 2014). Another possibility is that models, such as AHBF (Williams et al., 2019), could be slightly modified based on the observances from the WANT model (**Figure 3**). Such a model may consider the bi-directional nature of wants and urges with affect, emotion and mood. Can unsatisfied and unremitting urges and cravings exponentiate through worsening mood in a cyclic fashion? Understanding the complex relationships between these factors has significant implications for movement-based interventions.

(6) The processes primarily described here predominantly relate to automatic and impulsive processes, but much needs to be done to formulate how desires/urges interact with deliberative (reflective) processes. Certainly, impulses can be overridden by higher order cognition (e.g., goals) (Stults-Kolehmainen et al., 2020) and desires can relate directly to goals (Gernigon et al., 2004). Feige (1976) suggests that motivation for physical activity is a 5-level hierarchy, with drives to be active forming the foundation and goals and values in the highest level. These interactions have already been briefly detailed by theories, such as ART and AHBF, but also by: (a) the Model of Goal Directed Behavior, in which desires interact with intentions to pursue a goal (Dholakia, 2015), (b) the Grounded Theory of Desire and Motivated Behavior, in which environmental cues can spark memories, cognitions and mental re-enactments, which generate desires (Papies et al., 2020), and (c) the Elaborated Intrusion Theory, in which suppression of desire-related thoughts can lead to stronger desires (Andrade et al., 2015). Interactions between desires/urges and deliberative processes are also prominent in research on clashes between these constructs, as in work on: (a) want-"should" conflicts (Bitterly et al., 2015), (b) goal-desire conflicts (Hofmann et al., 2015), and (c) desires, reasoning and self-regulatory failure (deRidder et al., 2015). To summarize, there appears to be bi-directional and dynamic relationships between desires and goals; desires can hijack thoughts, be diminished by thoughts, work with thoughts toward a goal or undermine a goal.

(7) One question yet to be resolved is concerning a hierarchical typology for desires to move. More specifically, how do we distinguish between the human need to move for the sake of movement (primary desires) or simply to acquire something or accomplish some other task (secondary desires) (Reiss, 2004)? For instance, it is a common sensation to feel the urge to move when needing to urinate (Coyne et al., 2012), but this urge is secondary to the primary motive. More information is needed on how wants to move relate to wants for structured exercise or "working out," getting stronger, becoming leaner, etc., whether complimentary or not (Katula et al., 2006).

(8) Up to this point, there was a lack of validated instruments to assess desires/urges for movement and sedentary behavior. However, this gap was just recently addressed with the creation of the CRAVE (Cravings for Rest and Volitional Energy Expenditure) scale to measure desires/wants for movement and sedentary behavior (Stults-Kolehmainen et al., 2020). This novel instrument must be further investigated and validated under different conditions (e.g., prolonged sedentary behavior, different psychological moods, and different exercise activities).

(9) Future investigations should also be sensitive to linguistic and cultural differences. For instance, how desires, wants, urges and cravings translate in Portuguese might correspond to the words desejo or vontade (desire), querere (want), impulso (urge), necessidade or ânsia (craving) or even saudades – intense desires or longings for almost anything that is missing (Neto and Mullet, 2014).

(10) Utilize the concepts of desires/urges to move to explain other phenomena of interest. We focus on two examples. First, desires/urges for movement and rest might moderate the relationship between psychological stress and physical activity (Stults-Kolehmainen and Sinha, 2014), which seems to fit within the tenets of the AHBF-IF model (Williams et al., 2019). Second, the development of this concept may also be expanded to inform how energy availability (e.g., overfeeding or a deficit), and more generally nutrition, affects urges to move or be sedentary. For instance, a surplus of calories might result in altered desires to move for some people, which then may influence variations in non-exercise activity thermogenesis (NEAT), particularly spontaneous physical activity (i.e., fidgeting, posture adjustments) (Levine et al., 1999; Rosenbaum and Leibel, 2016) and other compensatory behaviors (King et al., 2007).

Such considerations provide fodder for a multiplicity of future investigations.

## Practical Implications

Understanding the underpinnings that lead to desires/urges for movement or rest may have vast practical implications in fields such as exercise science, motor control, performance, and physical therapy. Unfortunately, up until this time motivation states for movement were overlooked, considered irrelevant or categorized as a nuisance factor other than a real point of possible intervention. For instance, Williams et al. (2019) did not identify motivation states as a possible route of intervention in their integrated framework. However, given the potential stated above it is reasonable to consider methods that can enhance the desire to move. There are six general approaches relating to desires and urges: (1) To improve movement wants, modifying the reward value of exercise by making it less punishing and/or more pleasurable (increasing the "like"), (2) varying physical activity and exercise to result in less rapid satiation of desires, (3) modifying environmental and situational conditions to either ramp up motivation states to move and/or possibly dampen motivation states for rest, (4) modulating psychological attention to these desires so individuals might be more sensitive/attuned to desires, both noticing them when they occur and acting on them and (5) "nudging" people in response to these noticed desires/cravings, particularly with cues (Thaler and Sunstein, 2008; Hofmann et al., 2015), and (6) taking advantage of urges/desires for other rewarding behaviors to encourage development of desires to move. Regarding this last point, some work is already being done on gamifying movement, making games contingent on moving (e.g., Pokemon) to increase the reward value of movement (Kaczmarek et al., 2017).

It seems sensible to start with this approach of modifying exercise. Can exercise be modulated to make it more rewarding, and thus result in greater "wants"? Exercise can be modified to increase enjoyment by focusing on preferences (Stults-Kolehmainen et al., 2013; Busch et al., 2016) or reduce punishing aspects of exercise, like avoiding eccentric contractions (Kerksick et al., 2009) or excessive buildup of lactate and fatigue (e.g., minimized with sprint interval training – SIT) (Benitez Flores et al., 2018; de Sousa et al., 2018). It is likely important to avoid sudden, large increases in novel physical activities that result in excessive muscle damage and soreness, which are associated with decreases in physical activity (Proske, 2005; Stults-Kolehmainen et al., 2014) and negative shifts in mood (O'Connor et al., 1991; Stults-Kolehmainen and Bartholomew, 2012). We could also modify conditions to promote desires so that desires/urges are felt more frequently and/or with greater intensity. For instance, music often leads to muscular movement as humans can sense desires to move in response to a beat (i.e., groove), and musical cues appear to elicit neural firing (Levitin et al., 2018). It is likely that humans can even form internal representations of a beat so that anticipatory movement can occur in preparation for music, which is coordinated by the cerebellum, the supplementary motor area and the pre-motor cortex (Levitin et al., 2018). Motivational videos and other visual images (i.e., highly fit individuals, major sport feats, etc.) may also stimulate improved movement motivation and performance (Barwood et al., 2009; Cope et al., 2018). Environmental conditions, particularly daylight, can have a significant impact on levels of physical activity (Tucker and Gilliland, 2007). While weather cannot be changed, contingency plans can be put into place to modulate desires to move, and thus behavior, in response to varying conditions. One might imagine that it is possible to nearly perfect exercise conditions (e.g., ambient lighting, exercise-related imagery, diet, music, social interactions, acceptable stimulants, like caffeine) to facilitate greater muscular movement. Undoubtedly, coaches, commercial gyms and others already engage in such efforts to create attractive environmental and motivational climates to spur movement and its enjoyment (Shaulov and Lufi, 2009; Bird and Karageorghis, 2020).

Regarding approach 4, a large literature, starting with Libet et al. (1983) demonstrates that even healthy and well-functioning individuals can be trained to pay attention to urges for movement (Lau et al., 2004). Unfortunately, protocols in these studies have not been used in attempts to facilitate greater movement but were designed to investigate the control of movement. Perhaps simply asking someone about their desires/wants to move can instigate motivation states for movement. In populations suffering from addiction or stress, mindfulness meditation has been used to help individuals sense desires and then "ride the wave," interpreting appetitive stimuli as "mere mental events" as a method to cope with dysfunctional urges (Braun et al., 2012; Papies et al., 2015, 2020; Jastreboff et al., 2018). In line with these advances, perhaps a method, such as mindfulness and/or vivid imagery, could be developed or modified to promote greater movement (Kavanagh et al., 2005). This might involve generating desires/urges to move or simply paying attention and "listening" to them, thus bringing them fully into conscious awareness, gauging them, and consequently acting or consciously not acting on them (Devereaux, 2013; Naves-Bittencourt et al., 2015; Stults-Kolehmainen et al., 2015; Keesman et al., 2016; Renner et al., 2019; Papies et al., 2020). This approach seems promising but is still theoretical, and its efficacy is unknown.

## CONCLUSION

We conclude that there is a conceptual basis for desires and urges to motivate human movement and sedentary behavior. Such understanding is still in its infancy, particularly because of numerous similar concepts in literatures isolated from each other and a corresponding lack of coherence in definitions. Nevertheless, desires and wants for movement appear to be common constructs across multiple relevant theories. The current investigation conceptualizes physical activity primarily as a negative reinforcer. Humans likely have a "need for activity" that varies in intensity across the population (Rowland, 1998; de Geus and de Moor, 2011), is not simply a lack of "need to rest," and may be felt as tension when unsatisfied. These salient, internal cues may elicit wants or desires to rest and move, in other words, fluctuating states of motivation to either expend energy or be sedentary. In some situations, or for individuals with certain conditions, desires for activity may be experienced as urges or even cravings (Ferreira et al., 2006). This manuscript describes the WANT (Wants and Aversions for Neuromuscular Tasks) model, a circumplex model of wants and urges for movement and rest, where these factors are placed orthogonally. This heuristic might help to inform how movement and rest wants might be observed in a variety of situations. Unfortunately, no models specific to movement and rest exist to explain both how desires are precipitated and exert influence. Such models should expand beyond the automatic and impulsive level of processing predominately described in this manuscript to include interactions between desires/urges and reflective factors. The AHBF-IF is, perhaps, closest to this proposed model. Up to this point, instrumentation to measure desire has been lacking. However, the recent validation of the CRAVE Scale is an example of an advancement that might facilitate further understanding of why and how changes in movement and sedentary behavior occur across the day. Data generated in this regard may help to understand daily fluctuations in energy expenditure in both healthy, formal functioning populations as well as clinical populations where perception and manifestation of muscular movement is problematic. It is our desire that this conceptual analysis will provide a starting point for future investigations.

## AUTHOR CONTRIBUTIONS

MS-K, MB, RS, JB, TG, GA, and PM (in order by contribution) developed the conceptual analysis, wrote the manuscript, and designed and created the figures. All authors contributed to the article and approved the final submitted version.

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BRIEF RESEARCH REPORT
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# Recall of Affective Responses to Exercise: Examining the Influence of Intensity and Time

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Affective responses to exercise are noted to be dynamic and frequently vacillate between positive and negative valence during physical activity. Recalled affect following exercise can influence anticipated affective responses to exercise and guide future behaviors. Research examining affective memory processes indicates that the recall of an experience can substantially differ from the actual experience and change over time. Grounded in the dual mode model (Ekkekakis, 2003), this study examines individuals' recall of exercise-related affect over a period of 2 weeks. Forty-two adults (26 women, 16 men; $M_{age} = 29.64$, $SD = 5.69$) completed two 20-min treadmill exercise trials in a randomized control crossover design; the trials were set either at a low or high exercise intensity based upon individuals' ventilatory threshold. Data analyses indicate that the affective responses to the low-intensity condition were evaluated more positively than in the high-intensity condition. Recalled affect fluctuated over a 2-week time period following both the low- and high-intensity exercise trials. A significant reduction at the 24-h recall measurement point was observed in both exercise intensity conditions. Implications for future research and health promotion interventions aiming to optimize affective responses to exercise are presented.

**Keywords: affective responses, affective valence, recall, dual mode model, exercise intensity**

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## INTRODUCTION

In attempts to increase understanding of the mechanisms underlying the global issue of physical inactivity (Troiano et al., 2008; Ding et al., 2016), contemporary research increasingly focuses on factors that influence individuals' perceptual experience of exercise (e.g., Kwan and Bryan, 2010; Ekkekakis et al., 2013; Hutchinson et al., 2020). Numerous studies highlight that positive affect experienced during exercise is a significant predictor of future exercise behavior (for review, see Rhodes and Kates, 2015); conversely, experiencing discomfort, unpleasant affect, or pain during exercise is likely to contribute to a discontinuation of engagement in physical activity (Ekkekakis, 2003; Brand and Ekkekakis, 2017).

Extensive research of affective responses to exercise has been guided by Russell's (1980) circumplex model of affect comprising the dimensions of valence and arousal; primarily studies have focused upon how pleasant versus unpleasant (i.e., valence) individuals perceive the experience of physical activity to be (e.g., Williams et al., 2012; Williams and Raynor, 2013). Over a period of 50 years of research, the widely promoted "feel good" effect of exercise has been scrutinized (Ekkekakis et al., 2011; Ekkekakis and Brand, 2019); further, popular claims extolling the virtues of high-intensity interval training related to the cliché "no pain, no gain" have been the focus of recent affect-related research (Stork et al., 2018; Niven et al., 2020; Roloff et al., 2020). Numerous studies highlight that affective states derived from exercise are not purely positive; rather, over the course of exercise, affective states vary, and typically shift between pleasant and unpleasant hedonic valence (Backhouse et al., 2007; Ekkekakis et al., 2008; Rose and Parfitt, 2012). One explanation forwarded in an attempt to outline the extent of variability in affective responses during exercise is the dual mode model (DMM; Ekkekakis, 2003; Ekkekakis and Acevedo, 2006). The DMM posits that, when exercise intensity is below the point of the ventilation threshold (VT), individuals tend to derive greater pleasure from exercise. However, when exercise intensity is high and exceeds an individual's VT, the experience tends to generate less pleasant affect and increase unpleasant affect. The shift in affective responses has been accounted for by the domination of interoceptive cues (e.g., pain in leg muscles or the perception of being out of breath), which are strongly associated with unpleasant affect (Ekkekakis et al., 2004, 2008).

Early studies of affective responses associated with exercise typically measured affect pre and post sessions with more recent research advancement incorporating measurement during activity (Backhouse et al., 2007; Ekkekakis and Brand, 2019). Further, it was presumed that, upon exercise completion, the evaluation and memory of affective responses associated with the task remained constant over time and reflected a composite affective state (e.g., Williams et al., 2008). However, research on behavioral economics and social cognition of the memory of affective experience (e.g., Kahneman et al., 1993; Baumeister et al., 2001; Miron-Shatz et al., 2009) highlight that, rather than a composite affective state, individuals tend to remember particular segments of an experience, and the recall is prone to changes over time. In particular, the memory of the affective experience, rather than the actual affective experience, plays a central role in individuals' decisions about whether or not the behavior is repeated (Kahneman et al., 1997; Fredrickson, 2000).

In light of the role of memory in exercise-related affect, more recent research has investigated how individuals perceive their affective responses during physical activity as well as how the affective experience is remembered and recalled over time (e.g., Zenko et al., 2016). In particular, individuals who complete physical activity with greater positive affect and a lower exercise intensity remember the experience of the entire exercise session as more pleasant in comparison with individuals who complete their exercise at a higher intensity (Hargreaves and Stych, 2013). In explaining this predisposition, it is suggested that individuals do not consider the entire duration of exercise experience; alternatively, salient pieces of information (i.e., the peak and end) form the composite memory of the experience (Fredrickson, 2000).

The remembered affective experience of physical activity has been noted to influence the anticipated affective responses to subsequent sessions of physical activity (Kwan et al., 2017; Davis and Stenling, 2020). Although this observation is important for physical activity promotion, a limitation that arises from the aforementioned studies relates to the timing of the post-exercise measurement of remembered affective experience. Specifically, Kwan et al. (2017) study collected remembered affect only once at a time point 5 min post-exercise; Davis and Stenling (2020) measured remembered affect twice, but at intervals that were in close proximity to the completion of physical activity (i.e., 90 s and 3 min) and commencement of the subsequent session (i.e., 10 min). Repeated measures of remembered affective responses to exercise collected over a longer period of time (e.g., the following day) may elucidate the dynamic changes in remembered affective states over time.

Recent studies examining the role of affect in physical activity and lifestyle behaviors have used ecological momentary assessments (EMA) to capture experiences in naturalistic settings and to better understand patterns of change that occur over time (e.g., Ivarsson et al., 2020; Smith et al., 2020). In particular, a review of studies using EMA determined that higher levels of positive affect predicted greater physical activity within the next few hours and vice versa; however, the negative affect–physical activity relationship was mixed (Liao et al., 2015).

A potential explanation for the mixed findings of negative affect may relate to the timing of measurements of affective states and physical activity; current affect is predominantly the focus of assessment and, in turn, is associated with subsequent activity (Kim et al., 2020). Recent research examining the recall of past affective experiences using EMA notes a recall bias (i.e., the tendency to overestimate and/or underestimate positive or negative past emotional experiences; Colombo et al., 2020); however, research in the domain of exercise has not examined temporal aspects of recalled affective responses to exercise using EMA.

Taken collectively, previous research suggests the examination of changes in exercise-related affect over time is likely to offer insight into how individuals recall the experience of exercise and potentially explicate mechanisms underpinning individuals' exercise behaviors (Backhouse et al., 2007). The present study aims to advance understanding of the links between affect and exercise by investigating individuals' recall of their affective experience associated with exercise. Guided by the DMM (based on individuals' VT), the present study examines individuals' affective experiences during two exercise trials (high vs. low intensity) as well as their recall of exercise related affect over a 14-day period following each trial. In line with previous research, we hypothesized that affect experienced during low exercise intensity would be more pleasant than during high exercise intensity. Further, we hypothesized that the memory of exercise-related affect would not mirror the affective experience during exercise and would fluctuate over the 14-day recall period in relation to the exercise intensity conditions.

## METHODS

### Participants

The study sample consisted of 42 adults (26 women, 16 men; $M_{\text{age}} = 29.64$, $SD = 5.69$); at the time of recruitment to the study, participants completed a health survey to confirm that they did not suffer from any physical injury, had no history of cardiovascular, or respiratory disease, and were currently physically active and able to engage in moderate exercise.

Participants were recruited via a generic email, which was sent to undergraduate and postgraduate students at the university where the data were collected. Upon agreement to take part in the study, participants provided written informed consent. The study received institutional ethical approval from the university where the data were collected.

## Measures

### Affective Responses

The core affective dimension of valence was assessed by the Feeling Scale (FS; Hardy and Rejeski, 1989). The scale entails an 11-point bipolar measurement scale of pleasure–displeasure, ranging from +5 (*I feel very good*) to −5 (*I feel very bad*) with anchors at zero (*neutral*), participants were asked to rate "*How do you feel?*" Concurrent validity data have been previously reported by Hardy and Rejeski. The FS was used to measure affective responses prior to, during, and after each of the exercise trials (i.e., low and high exercise condition). In consideration of the nature of the experiment, a single-item rating was evaluated as most adequate as it limited the burden of data collection being placed upon participants during exercise bouts.

### Remembered Pleasure

Recall of affective experience was measured with the Global Affective Evaluation Scale (GAE; Schreiber and Kahneman, 2000), which has previously been used to measure the overall amount of pleasantness or unpleasantness experienced during exercise (Hargreaves and Stych, 2013). The scale has a range from −10 (*very unpleasant experience*) through 0 (*neutral experience*) to +10 (*very pleasant experience*); participants were asked to "*Please rate the overall amount of pleasantness of unpleasantness that was experienced during the previous exercise trial.*"

The Rating of Perceived Exertion Scale (Borg, 1998) was used to assess whole-body ratings of perceived exertion (RPE). Participants stated the number that reflected how difficult the exercise felt on a 6–20 scale, ranging from 6 (*no exertion at all*) through 13 (*somewhat hard*) to 20 (*maximal exertion*). In line with recommendations from Borg (1998), participants were provided standardized instruction on how to use the scale and time to practice during the familiarization session.

## Procedure

### Maximal Graded Treadmill Test

In order to determine individuals' ventilation threshold (VT), prior to the first exercise trial, maximal aerobic capacity ($VO_{2max}$) data were collected. Participants competed the incremental treadmill test based on the Balke-Ware test protocol (ACSM, 2006). The analysis of pulmonary gas exchange was recorded continuously with an online gas analyzer (Oxycon Pro, Jaeger, Germany). The attainment of maximal aerobic capacity was verified by at least two of the following criteria: (i) a peak or plateau in oxygen consumption (changes <2 ml. $kg^{-1}$ $min^{-1}$) with increasing workload; (ii) reaching age-predicted maximal heart rate (i.e., 220—age); and/or (iii) a respiratory exchange ratio of at least 1.1. $V_{O2peak}$ was established at the point where $V_{O2}$ attained the highest value after reaching the criteria. The V-slope method was then used to determine individuals' VT. $V_{CO2}$ was plotted against $V_{O2}$, and from visual examination of the graph, VT was determined at the point where the first inconsistent increase in $V_{CO2}$ occurred (Gaskill et al., 2001).

### Exercise Sessions

Upon arrival at the laboratory, participants were asked to complete a self-reported measure of affective responses (FS). Individuals were randomly assigned (using a web-based online randomizer application; random.org) to one of the two exercise intensity conditions: 10% above-VT and 20% below-VT (based on previously determined individual point of VT). Depending on the randomization, participants were asked to run for 20 consecutive minutes on a treadmill that was set at either a high (above-VT) or low (below-VT) pace. Preliminary baseline measurements were collected immediately prior to commencing the exercise trial; specifically, affective responses (FS) were recorded immediately before the task commenced and repeatedly every 5 min for the remaining 20 min of the exercise task along with the measure of RPE (Borg 10). For the purpose of capturing fluctuation in affective responses over time, the measure of FS was recorded 1 min into a cool-down period of light running, as well as 5, 10, and 15 min post exercise, followed by another 4 points in time (i.e., 4, 24 h, 7, and 14 days post-exercise at the same time of day as when the exercise trial was completed). Participants were asked to complete the measure of GAE at 5 and 15 min post-exercise, and then at another 4 points in time (i.e., 4, 24 h, 7, and 14 days). Participants were asked to attentively follow the instructions for the post-exercise measurement by reporting their affective evaluation in a timely fashion via an online survey (surveymonkey.com). The responses were prompted by a notification sent to participants' mobile phones via text message approximately 30 min before the designated time of the measurement.

Following a 2-week period of time from the first exercise trial, the second exercise trial was undertaken. The second trial was completed using the same measurement protocol as detailed in the first trial. In the second exercise trial, those participants who previously exercised at an above-VT pace now performed the below-VT condition, whereas those who performed the first trial in the below-VT condition exercised at an above-VT pace in the second trial. To reduce expectancy effects, the participants were informed that the intensity may range from a low to a high exercise intensity based on their individual capacity measured at $V_{02max}$ test taken previously.

## Statistical Analysis

To examine within-subject changes in current affect (FS) and recalled affective experience (GAE) over time at a group level, repeated-measure ANOVAs were used. The EMA method was used to analyze within-subject variations in current and recalled affect in everyday life. EMA has been successfully used in previous studies examining mood and physical activity (Hausenblas et al., 2008; Kanning and Schlicht, 2010). All statistical procedures were conducted in IBM SPSS version 20 statistical software.

## RESULTS

Data collected from post-exercise measurement points showed that a number of participants failed to complete all of the post-exercise survey questions over the course of 28 days ($N = 13$; 32.5%). However, IBM SPSS 20 does not account for missing data from participants who omit one or more measurement points over the 2-week periods of data collection. Subsequently, data from 27 participants were subject to a maximum likelihood estimation using the expectation maximization algorithm to estimate and impute missing data based on the available responses. This method has previously been used in longitudinal studies in an exercise context (Helfer et al., 2015). In order to avoid estimating data based on inadequate information, participants were excluded if they were missing more than 40% of the follow-up surveys (van Ginkel and Kroonenberg, 2014). The data (GAE, FS) collected during the two experimental exercise conditions (below VT, above VT) were included in the estimation algorithm as predictors of missing values, and estimates were constructed by applying the Missing Value Analysis function.

### Affective Responses

Repeated-measures ANOVAs showed significant changes in affective responses over time during and after low-intensity exercise $F(13, 38) = 6.85$, $p < 0.001$, $\eta^2 = 0.15$ and high-intensity exercise $F(13, 38) = 7.49$, $p < 0.001$, $\eta^2 = 0.16$. **Figure 1** illustrates patterns of how individuals feel with changes prior, during, and after the low and high exercise intensity.

### Recall of Affective Experience

The descriptive data reflecting the recall of affective experience is displayed in **Table 1.**

Results show the recalled exercise-induced affective valence that was reported in the postexercise evaluations was subject to fluctuations. The repeated-measure ANOVAs indicate significant changes in recalled affect in the low-intensity exercise trial $F(8, 39) = 3.14$, $p = 0.012$, $\eta^2 = 0.29$, and in the high-intensity exercise trial $F(8, 39) = 3.89$, $p = 0.03$, $\eta^2 = 0.34$. Further, pairwise analyses revealed significant differences between the 8 and 24 h post-exercise measurement points in the low-intensity condition $t(39) = 3.22$, $p < 0.01$, $d = 0.75$ and high-intensity condition $t(39) = 2.02$, $p < 0.05$, $d = 0.55$. Overall, the low-intensity condition was evaluated more positively than the high-intensity condition.

### Predicting Recalled Affective States at 24 h Post-Exercise

Multiple regression analyses were used to examine the impact of affect experienced during the exercise trials and affect remembered from exercise on the 24-h measurement point of recalled affective state. In the low exercise intensity condition, four measurement points of feeling states obtained during exercise together with the first five recall measurements of affective states, measured with GAE at 1, 5, 40 min, 4, and 8 h accounted for 88% of variance of the recalled affective state at the 24-h measurement point $F(9, 36) = 21.89$, $p < 0.001$. Coefficient analysis shows that two independent variables, recall at 4 and 8 h were significant. In the high exercise intensity condition, the four measurement points of feelings states obtained during exercise together with the first five recall measurements of affective states explained 92% of the variance of the 24 h measurement point $F(9, 36) = 21.89$, $p < 0.001$) with an $R^2 = 0.92$.

## DISCUSSION

The aim of the present study was to examine how individuals recall their affective experience of two exercise conditions (i.e., low and high intensity). The results indicate that the recall of affective experiences after exercise continues to fluctuate regardless of whether the exercise intensity is low or high. Therefore, these findings contrast with the commonly held presumption that post-exercise affect remains constant after exercise is completed. However, these results are in line with research suggesting that the affective memory of exercise is comprised of information that does not reflect the exact affective experience during exercise (Hargreaves and Stych, 2013). The results of the present study indicate that high-intensity exercise is evaluated less positively than low intensity exercise. These finding are in line with the DMM, which explains that, during the low-intensity exercise, there is a larger role of cognition, and the exercise is typically perceived as more pleasant, and during high-intensity exercise, a heavier role is played by physical factors, such as interoceptive cues (e.g., pain in the leg muscles or perception of being out of breath), which are strongly associated with negative unpleasant affect (Ekkekakis, 2003; Ekkekakis et al., 2004, 2008). The current study findings can also be extended to related research linking the experience of exercise with adherence; specifically, exercising at high intensity is associated with less positive experience and significantly lower rates of adherence than low or moderate exercise intensity (DaSilva et al., 2011).

A key finding arising from the present study notes that the recall of affective responses declines in reported valence significantly at the 24-h post-exercise measurement point. The research literature offers two possible explanations for a decrease in the recall of affective responses at 24 h post-exercise, one is a termination of the anxiolytic effect from exercise (Ebbesen et al., 1992; Salmon, 2001; Kwan and Bryan, 2010). A study by Ebbesen et al. (1992) highlights that exercise attenuates perceived stress for a period between 1 and 3 h after exercise, but the effect does not extend to 24 h. Kwan and Bryan (2010) demonstrate that, after a submaximal bout of exercise, an individual's level of tranquility is raised above baseline levels with measurements of tranquility recorded at 15 and 30 min post-exercise; the observed effect was maintained across the two time points. The authors conclude that, if increased exercise-related feelings of tranquility persist throughout the day, regular exercise behavior may reduce stress.

Another plausible explanation for the observed decline in affective valence 24 h post-exercise relates to delay onset muscle soreness (DOMS; Cheung et al., 2003) following unaccustomed exertion, which tends to occur ∼4 to 8 h after exercise. Participants' recall of affect at the 24-h measurement point could have been biased by the salience of DOMS when evaluating the exercise experience. These explanations are two

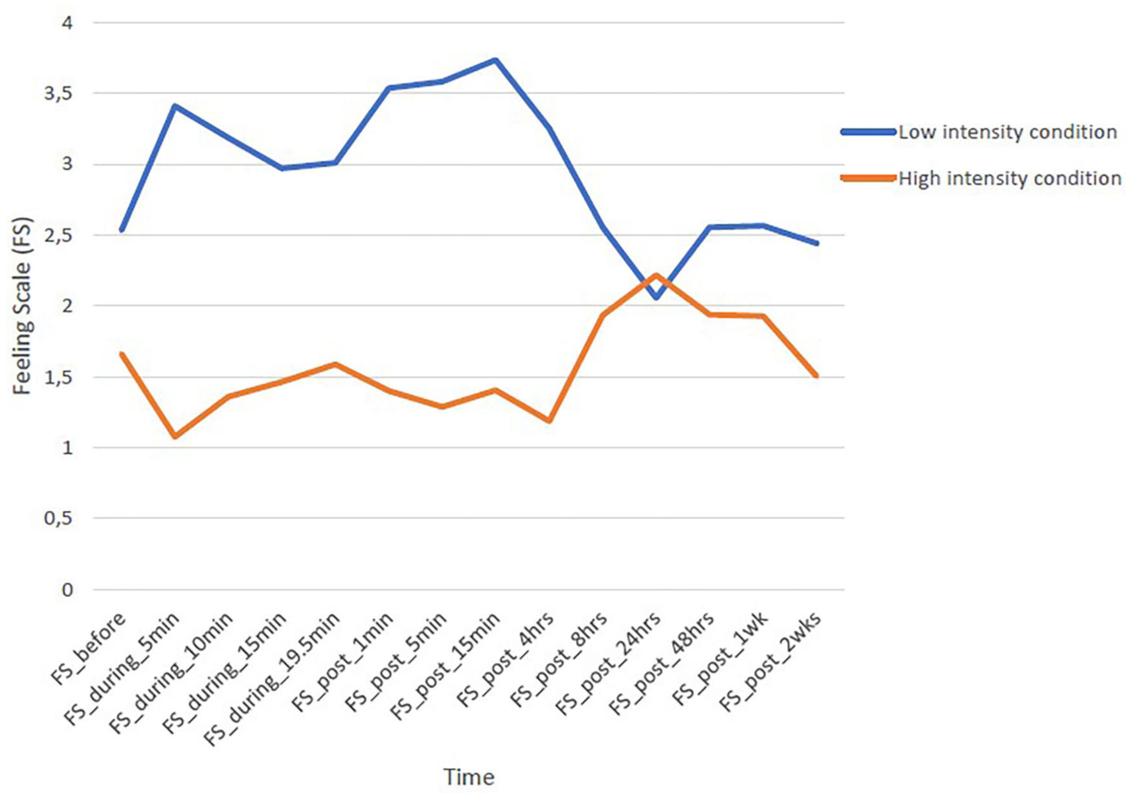


**FIGURE 1 |** Changes in feelings states (FS) prior, during and after low and high exercise intensity.

**TABLE 1 |** Descriptive statistics of recall of affective experience (GAE).

| Time | 1 min post | 5 min post | 15 min post | 4 h post | 8 h post | 24 h post | 48 h post | 1 week post | 2 weeks post |
|---|---|---|---|---|---|---|---|---|---|
| Low intensity *M* (*SD*) | 6 (3.01) | 5.69 (3.30) | 6.28 (3.11) | 6.30 (2.86) | 6.29 (3.16) | 5.10** (3.79) | 5.58 (4.06) | 6.44 (3.20) | 5.77 (3.14) |
| High intensity *M* (*SD*) | 3.1 (4.37) | 3.56 (3.39) | 2.82 (5.10) | 3.07 (4.97) | 2.71 (5.16) | 1.97* (5.04) | 2.64 (5.18) | 2.77 (4.64) | 3.54 (4.98) |

**$p < 0.01$, *$p < 0.05$.

potential mechanisms underlying the affective decline observed in recall at 24 h; however, further research is required to test these explanations.

Some studies show that long-term exercise is positively associated with positive affect during and after exercise (Arent et al., 2000; Schneider et al., 2009); affect can provide feedback regarding the exercise experience and serve as a powerful motivational tool in exercise adherence. Affective feedback can promote approach or avoidance behaviors, either toward or away from future repeat experiences, depending on how the experience is remembered and the outcomes that are anticipated (Baumeister et al., 2007; Brand and Ekkekakis, 2017). In regards to exercise, it is common that, upon completion, one feels positive and may likely think of engaging in exercise in the following days. However, contrary to immediate post-task planning, the actual decision to initiate another bout of exercise occurs at a later point in time. The current study shows that the memory of exercise-induced affect is prone to changes over time. At a time of decision making, the recall of affective experience from exercise is likely to be an important factor to construct the anticipatory affective states. Previous study shows that individuals who anticipate a more pleasant affective experience from exercise report higher, positive affective responses during the subsequent exercise trials (Davis and Stenling, 2020). Findings obtained from the present study raise important applied implications for professionals aiming to optimize health and high performance as well as the development of training programs designed to maximize exercise adherence. Training plans should consider temporal fluctuations in the recall of exercise-related affect and implement strategies that attempt to minimize observed patterns of diminished positive affect.

Prospective studies should further examine the process underlying individuals' decision to engage in repeat exercise by attempting to understand how recalled exercise-induced affect interacts with evaluative processes that guide exercise behavior. Similarly, future studies may consider using qualitative research methods and to examine the recall of exercise-induced affect 24 h postexercise. Further study is also warranted to determine if the observed drop in positive recalled affect at 24 h postexercise is present if individuals are participating in a longer program of exercise and are scheduled to exercise again within the following days.

### Limitations and Future Directions

A clear limitation of the current study is that, during the 2-week recall period, neither meaningful life events nor an actual level of physical activity were controlled for, which could have an impact upon the recollection of the previous affective experience of the exercise activity. Although participants were strongly advised that they should refrain from physical activity, it cannot be presumed with certainty that they adhered to the advice. Furthermore, the potential explanations that were offered to account for the decline in recall of affective experience (i.e., the termination of anxiolytic effect of exercise and DOMS) are only hypothetical; individuals who took part in the study were not specifically examined for these potential mechanisms. Henceforth, future studies should undertake the examination of these proposed explanations and assess whether individuals actually experience a termination of anxiolytic effect or a DOMS during post-exercise evaluation.

Based on the findings from the study, it is important for prospective studies to further examine when exactly people make decisions to engage in exercise in order to understand how exercise-induced affect that is recalled over time interacts with evaluative processes and as a consequence how it is integrated into decision making guiding future exercise behavior. Similarly, future studies may consider using a qualitative approach and more in-depth inquiry to further examine recalled affective experience from exercise with a particular focus on the 24-h post-exercise time point. Prospective studies may also examine if the 24-h post-exercise drop in the recall of affective experience persists if individuals are participating in a longer program of exercise and have scheduled another exercise session within the following days.

### Conclusion

In light of the escalating global issue of physical inactivity, the results from this study highlight an important underlying factor of exercise behavior by delineating how exercise-related affective states are remembered over time. Individuals' prospective exercise participation is guided by the recall of affective states experienced during the exercise. In a context where many competing activities can inhibit exercise, targeting post-exercise affective evaluation may enhance the effectiveness of physical activity interventions.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University Research Ethics Committee (REC) at Northumbria University. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

MS planned and designed the study. MS and PD contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

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REVIEW
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# Affective Determinants of Physical Activity: A Conceptual Framework and Narrative Review

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The literature on affective determinants of physical activity (PA) is growing rapidly. The present paper aims to provide greater clarity regarding the definition and distinctions among the various affect-related constructs that have been examined in relation to PA. Affective constructs are organized according to the Affect and Health Behavior Framework (AHBF), including: (1) *affective response* (e.g., how one feels in response to PA behavior) to PA; (2) *incidental affect* (e.g., how one feels throughout the day, unrelated to the target behavior); (3) *affect processing* (e.g., affective associations, implicit attitudes, remembered affect, anticipated affective response, and affective judgments); and (4) *affectively charged motivational states* (e.g., intrinsic motivation, fear, and hedonic motivation). After defining each category of affective construct, we provide examples of relevant research showing how each construct may relate to PA behavior. We conclude each section with a discussion of future directions for research.

**Keywords: affect, physical activity, exercise, Affect and Health Behavior Framework, affective response, incidental affect, affect processing, affectively charged motivational states**

## INTRODUCTION

The relationship between regular physical activity (PA) and health is indisputable (Rhodes et al., 2017; Warburton and Bredin, 2017; Guthold et al., 2018; Mandsager et al., 2018; Piercy et al., 2018). Data collected from population-based prospective cohort studies suggest that engaging in 1–5 times the recommended minimum amount of weekly PA is associated with a 31–39% reduced risk for all-cause mortality (Arem et al., 2015). Furthermore, the economic consequences of physical inactivity are exorbitant. A recent "global analysis" conservatively estimated the annual cost of physical inactivity to be $53.8 billion worldwide (Ding et al., 2016).

Both national and international PA guidelines specify that adults should "move more and sit less" and that "some PA is better than none" (World Health Organization, 2010; Piercy et al., 2018). However, to achieve substantial health benefits, adults aged 18–64 should do at least 150 min of moderate-intensity aerobic PA or 75 min of vigorous-intensity aerobic PA throughout the week (or an equivalent combination of both). Bouts of aerobic PA should be performed in sessions of at least 10 min duration and muscle strengthening activities should additionally be done 2 or more days per week and involve all major muscle groups

(World Health Organization, 2010; Piercy et al., 2018). Despite wide dissemination of these guidelines, only 23% of adults achieve guidelines for both aerobic and muscle strengthening PA, and 44% do not meet either guideline (USDHHS, 2018).

There is considerable public health incentive to identify strategies for increasing PA participation and maintenance in the population. A current topic of debate in the literature concerns the extent to which social cognitive theories, which have a long history of application in PA intervention research, have "outlived their usefulness" (Sniehotta et al., 2014; Linde et al., 2016), and the extent to which affective/experiential factors, historically omitted from dominant theoretical models, might help to elucidate the "intention-behavior gap" observed in PA research (Rhodes and de Bruijn, 2013; Sheeran and Webb, 2016; Rhodes and Gray, 2018). As such, efforts to understand who will, and who will not maintain PA over time have increasingly focused on affective correlates and determinants of behavior (Williams and Evans, 2014; Conner et al., 2015; Rhodes and Kates, 2015; Conroy and Berry, 2017; Ekkekakis, 2017; Brand and Ekkekakis, 2018; Williams et al., 2018; Ekkekakis and Brand, 2019).

According to the Affect and Health Behavior Framework (AHBF), first proposed by Williams and Evans (2014), affective correlates and determinants of health behavior can be divided into four categories with respect to their association with the target behavior (see **Figure 1**). These are (1) affective response, which is how one feels while performing a behavior and/or immediately after completing a target behavior; (2) incidental affect, which is how one feels throughout the day, outside the context of the target behavior; (3) affect processing, which concerns cognitive processing of previous affective responses and may be automatic (affective associations and implicit attitudes) or reflective (anticipated affective response, remembered affect, and affective judgments); and (4) affectively charged motivation, which includes motivational states that have their basis in past affective responses to PA and motivational states that include and/or have a basis in past affective responses to PA and are elicited through both automatic (hedonic motivation) and reflective (intrinsic motivation and fear) processing pathways. Numerous studies have explored the roles that these various affective categories play in predicting and/or promoting PA; however, at present, there have been no attempts to summarize these approaches within a single review.

The present article aims to apply the AHBF to the domain of PA and provide a selective review of relevant studies on affect-related correlates and determinants of PA. It is not the intention of this article to present a systematic and quantitative review of research on all affect-related factors but rather to distinguish among various affect-related constructs and provide an illustration of how each construct may relate to PA behavior. Consistent with the AHBF, the focus of the present review is on affective factors as putative determinants of PA behavior. That is, we are interested in PA behavior – not affect – as the dependent variable.

## Key Terminology

Before proceeding, a note on terminology is warranted. We use "PA" as a superordinate term to summarize and integrate findings across studies in which either purposeful exercise or PA (encompassing all daily kinesthetic movement including, but not limited to, activities performed for the purpose of exercise) was examined as the outcome of interest.

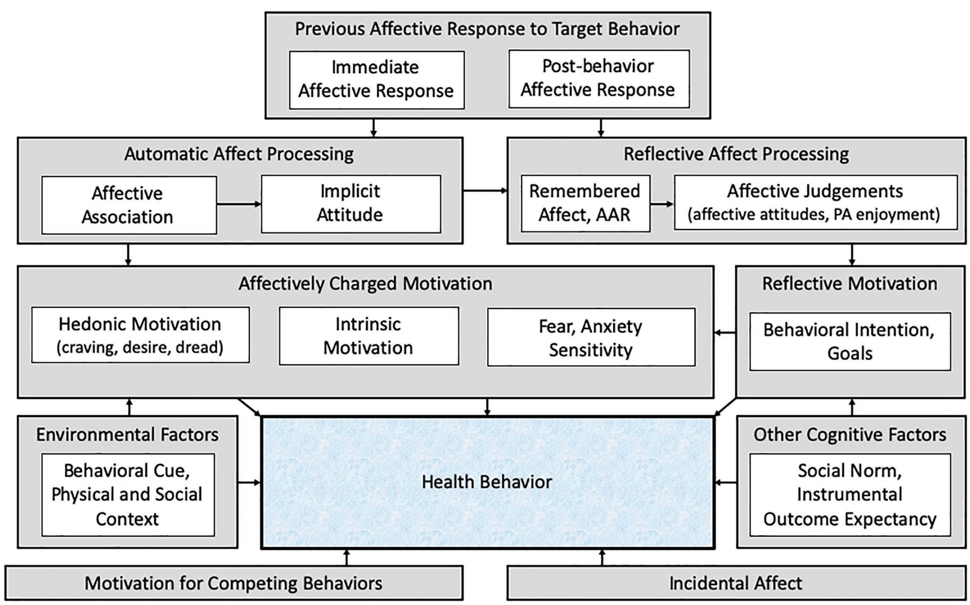


**FIGURE 1** | The Affect and Health Behavior Framework (adapted from Williams and Evans, 2014). AAR, anticipated affective response; PA, physical activity. Prior affective responses to a health behavior (physical activity) influence both automatic and reflective affect processing, which informs both affectively charged and reflective motivation to perform (or avoid) the behavior. Affect unrelated to the target behavior experienced throughout the day (incidental affect) also influences behavior, as do other cognitive factors, environmental factors, and motivation to perform other competing behaviors.

Further, we use the superordinate term "affect-related" to refer to the full range of constructs represented by all four AHBF categories (see **Table 1**). We do this to increase ease of readability as a wide range of affective states have been measured with respect to PA and relatedly use of affective terminology has varied across the literature (Ekkekakis et al., 2011; Ekkekakis, 2013). Conversely, the term "affect" will only be used to refer to affect *per se*, which includes core affect, emotions, and moods. The first two categories of constructs in the AHBF – affective response to PA and incidental affect – constitute affect *per se*, whereas the second two categories represent affect-related cognition and affectively charged motivation, respectively.

We also want to clarify terminology regarding core affect, as core affect is commonly used when measuring affect *per se* in relation to PA, and at times, there has been confusion about how to describe and label core affect. To summarize briefly, Russell (1980) proposed a circumplex model to describe core affect whereby two neurophysiological systems, valence (pleasure-displeasure) and arousal (energy-lethargy), give rise to all other feeling-based experiences (see **Figure 2**). Later, Watson and Tellegen (1985) proposed a rotated circumplex model of affect, which rotates the two core affective dimensions 45°, yielding two orthogonal dimensions: a positive activation dimension ranging from "positive activated affect" (e.g., energy and vigor) to "negative deactivated affect" (e.g., fatigue and boredom) and a negative activation dimension ranging from "negative activated affect" (e.g., tension and distress) to "positive deactivated affect" (e.g., calmness and relaxation).

**TABLE 1** | Affective determinants of physical activity (PA) represented in the Affect and Health Behavior Framework (AHBF).

| | |
|---|---|
| **Affective response** | |
| Definition | • How one feels while performing and/or immediately after completing a target behavior |
| Key features | • Affect, *per se*, can only be experienced *in vivo* |
| Constructs measured in relation to PA | • Core affect (valence and arousal) |
| Assessment | • Assessment by self-report (e.g., core affective valence): *Choose the number that best describes how you feel right now… "very bad"* (−5) – *"very good"* (+5)<br>• Measures may be administered in-person or remotely (*via* ecological momentary assessment) |
| **Incidental affect** | |
| Definition | • How one feels throughout the day, unrelated (incidental) to the target behavior |
| Key features | • Affect, *per se*, can only be experienced *in vivo* |
| Constructs measured in relation to PA | • Core affect, specific affectively charged states (fatigue), moods, and emotions |
| Assessment | • Assessment by self-report (e.g., negatively valenced affect): *How stressed are you feeling right now… "not at all stressed"* (+1) – *"extremely stressed"* (+5)<br>• Data often collected using ecological momentary assessment |
| **Affect processing** | |
| Definition | • Cognitive processing of previous affective responses |
| Key features | • Occurs through both automatic and reflective pathways |
| Constructs measured in relation to PA | • Automatic affect processing constructs: affective associations and implicit attitudes<br>• Reflective affect processing constructs: remembered affect, anticipated affective response, and affective judgments |
| Assessment | • Automatic affect processing assessment by reaction-time tasks (e.g., implicit attitudes): Participants respond to PA-related word or image cues paired with affective descriptors<br>• Automatic affect processing assessment by self-report (e.g., affective associations): *When I consider physical activity, I feel happy… "strongly disagree"* (+1) – *"strongly agree"* (+5)<br>• Reflective affect processing assessment by self-report (e.g., affective attitudes): *For me, engaging in moderate-vigorous PA would be…. "Very unpleasant"* (0) – *"Very pleasant"* (+100) |
| **Affectively charged motivation** | |
| Definition | • A motivational state that includes and/or has its basis in past affective responses to PA |
| Key features | • Occurs through both automatic and reflective pathways<br>• The counterpart to reflective motivation (i.e., goals and intentions) |
| Constructs measured in relation to PA | • Hedonic motivation (automatic desire/wanting vs. dread); fear/anxiety sensitivity |
| Assessment | • Intrinsic motivation is the mostly commonly assessed construct in this category and is assessed by self-report: *I get pleasure and satisfaction from participating in exercise … "strongly disagree"* (+1) – *"strongly agree"* (+5)<br>• Hedonic motivation (automatic desire/wanting vs. dread) has been assessed with one-item self-report measures but can also be assessed *via* neurobiological assays (e.g., "wanting" as dopamine release).<br>• More research is needed to distinguish self-report of hedonic motivation from reflective wanting or dread, which may be based on deliberate consideration of the long-term consequences of exercise (e.g., health benefits) and, thus, is not consistent with hedonic motivation. |

*PA, physical activity. Examples listed under assessments are intended to provide a brief illustration of how affect-related constructs from each category of the AHBF are commonly assessed in research. Examples are by not exhaustive.*

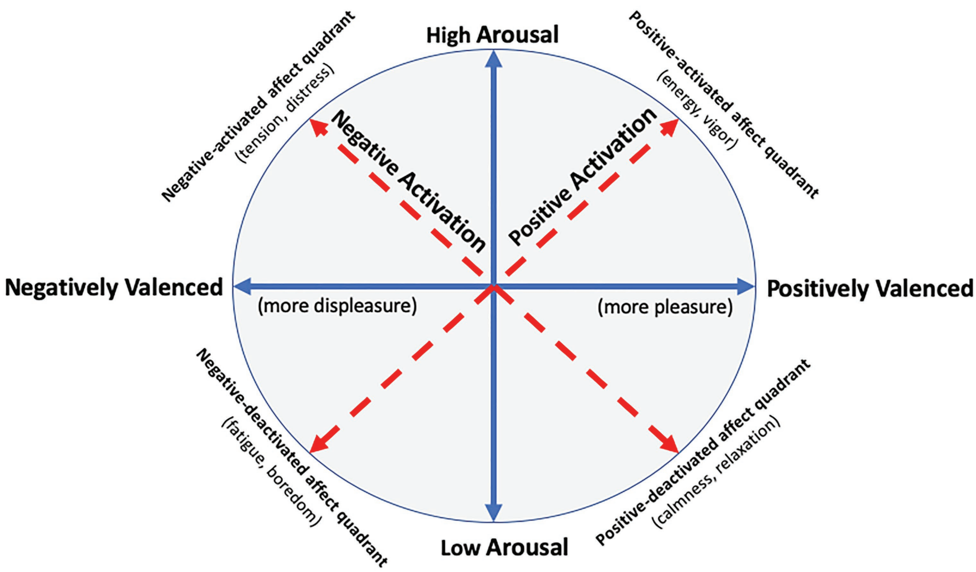


**FIGURE 2 |** Core affect as depicted by the unrotated and rotated circumplex models (adapted from Ekkekakis, 2013). Solid arrow lines (blue) represent the dimensions of the unrotated circumplex model of affect (Russell, 1980), and dotted arrow lines (red) represent the dimensions of the rotated circumplex model of affect (Watson and Tellegen, 1985) using the revised labels for each bipolar dimension (Watson et al., 1999). As depicted, the dimensions of the unrotated circumplex model generate four quadrants and certain measures of affect, such as the Physical Activity Affect Scale (PAAS; Lox et al., 2000), measure constructs that map onto these quadrants.

Initially, Watson and Tellegen labeled the dimensions of the rotated circumplex model [and the associated Positive and Negative Affect Schedule (PANAS); Watson et al., 1988] "positive affect" and "negative affect" because they believed the constructs were best defined by their high-arousal poles. There was significant debate in the literature regarding this choice (Feldman Barrett and Russell, 1998) and later Watson et al. (1999) published a paper that renamed the two dimensions as "positive activation" and "negative activation." Despite this, many authors continue to use the original labels for the rotated circumplex model's dimensions (i.e., "positive affect" and "negative affect"). This has led to the mistaken belief that the positive activation and negative activation dimensions of the rotated circumplex model are meant to reflect pure pleasure and displeasure, respectively, and that pleasure and displeasure may be conceptually orthogonal (see Ekkekakis, 2013). Therefore, although potentially more cumbersome, when referring to the valence dimension of Russell's (1980) unrotated circumplex model, we use the terms "positively (or negatively) valenced affective states" or "positive (or negative) shifts in affective valence" to distinguish these affective concepts from the (original) "positive affect" and "negative affect" dimensions of the Watson and Tellegen's rotated circumplex model.

## AFFECTIVE RESPONSE TO PA

Affective response to PA is how one feels in response to PA behavior. By this definition, affective response can only be experienced *in vivo* and, therefore, it should be measured while a participant completes his or her assigned PA on a treadmill (or other type of equipment). For example, a researcher might ask a participant to provide a rating on an affective response self-report measure, such as the Feeling Scale (Hardy and Rejeski, 1989), every few minutes during and immediately following the laboratory-based PA task (i.e., "Please choose the number that best describes how you feel right now on a scale from −5 = *very bad* to +5 = *very good*"). More recently, increasingly sophisticated and commercially available technology has made it possible for researchers to query participants' affective responses to PA in their natural living environments, in-real-time, through the use of ecological momentary assessment (EMA).

When the focus is on affective response to PA as a determinant of future PA, rather than as an outcome in its own right (e.g., PA as a treatment for depression or anxiety), it is, consistent with psychological hedonism, core affective valence (pleasure vs. displeasure; Russell, 1980) that is the most important aspect of affective response. Alternatively, there are no obvious theoretical or conceptual indications as to what specific affective states – sadness or embarrassment, joy or tranquility – might, in the context of affective response to PA, add to the prediction of future PA behavior beyond positive vs. negative affective valence (Ekkekakis and Petruzzello, 2000). Thus, much of the literature on affective response to PA as a putative determinant of future PA has, appropriately, emphasized core affective valence.

In any case, for purposes of understanding the potential influence of affective response to PA on future PA behavior, one should expect that, consistent with psychological hedonism, a positive shift on the affective valence dimensions (greater pleasure or less displeasure) or either an increase in positive activation or a decrease in negative activation in response to

PA behavior will lead to greater likelihood of future PA behavior. This idea – that people pursue pleasure and avoid displeasure – is a basic and ancient principle of human behavior and is referred to in the academic literature as "psychological hedonism" or the "hedonic principle" (Cabanac, 1992; Kahneman et al., 1997; Rhodes and Kates, 2015; Williams, 2018, 2019).

Another important factor when considering affective response to PA is the distinction between during-behavior and post-behavior affective response. As noted in the AHBF, this distinction is important because for many health behaviors the way one feels during behavior is markedly different and often has an opposite affective valence to how one feels immediately following the behavior (e.g., smoking or drinking lapses, drug use, and illicit sexual behavior). Indeed, while there is great variation in how individuals respond affectively during PA, affect post-PA is known to improve almost universally, this is known as the "affective rebound effect" (Ekkekakis, 2003; Ekkekakis et al., 2005, 2011; Jung et al., 2014; Cavarretta et al., 2019; Box et al., 2020).

## PA Intensity and Affective Response

While the focus herein is on PA as the dependent variable, factors that consistently determine affective response to PA are relevant to the extent that affective response to PA, in turn, determines PA behavior. The intensity of the PA stimulus is perhaps the factor most robustly associated with affective response to PA. Laboratory studies have demonstrated near-universal negative shifts in affective valence as PA intensity increases beyond the ventilatory threshold (VT); however, at intensities close to the VT, there is considerable intra-individual variation influenced by physical fitness, PA levels, body composition, and other cognitive factors (Ekkekakis et al., 2004, 2008).

According to Dual Mode Theory (Ekkekakis, 2003), shifts in affective valence in response to PA are determined by two orthogonal factors: cognitive parameters (e.g., self-efficacy, attitudes, and body image) and interoceptive cues (e.g., pain, temperature, and cortical oxygenation). Cognitive parameters influence affective valence at intensities below VT, such that, for example, holding more or less positively valenced affective attitudes about PA, or possessing more self-efficacy with respect to ability to perform PA may up- or downregulate affective valence, respectively. At intensities above VT and beyond, however, interoceptive cues dominate, evoking highly salient sensations of displeasure and overwhelming cognitive factors that may otherwise preserve or positively influence valence at lower intensities. Because the variability in affective response to PA most often occurs below VT, researchers studying affective response to PA typically set the exercise stimulus intensity to be at or near to a participant's individual VT.

Briefly, it noteworthy that a number of studies have explored what effect completing high-intensity PA in discrete intervals across a workout [e.g., high-intensity interval training (HIIT)], rather than at a continuous pace, has on affective response to PA. Consistently, these studies find that affective response is more negatively valenced in response to the high-intensity conditions (both when the high-intensity is performed in intervals and steady state) than in the moderate-intensity conditions (Jung et al., 2014; Niven et al., 2018; Box et al., 2020). One study examined the affective-rebound effect mentioned above but applied examination of this phenomenon to the rest periods during interval PA training. Specifically, Box et al. (2020) found participants completing a HIIT session experienced greater increases in positively valenced affect between intervals compared to participants completing a moderate-intensity interval training session, but this spike was not large enough to account for declines ("plummets") in affective valence during the interval sessions. Some research suggests that high-intensity PA might be more palatable if the intensity of the PA stimulus decreases over the course of the bout. For example, a study by Zenko et al. (2016) found that a "ramping down" approach (starting out with high intensity and declining toward the end of the bout) produced a positive affective response slope and yielded more favorable outcomes on post-PA affect processing constructs (i.e., remembered affect and anticipated affect) compared to a condition where intensity was increased over the course of the bout.

## Affective Response as a Putative Determinant of PA Behavior

A systematic review conducted by Rhodes and Kates (2015) summarized the extant literature regarding the relationship between affective response to PA and future PA behavior. They identified four studies examining during-PA affective response as a predictor of future PA (Williams et al., 2008, 2012; Schneider et al., 2009; Kwan and Bryan, 2010). Despite considerable variation in participant demographics (e.g., age and activity level), PA stimulus (e.g., cycle ergometer and treadmill), affect assessment [e.g., Physical Activity Affect Scale (PAAS; Lox et al., 2000), Feeling Scale (FS; Hardy, and Rejeski, 1989)], and PA assessment method (e.g., actigraphy and self-report), the relationship between affect experienced during PA and subsequent PA was positive in all four studies (Rhodes and Kates, 2015).

In two additional studies conducted after the Rhodes and Kates (2015) review, further support was shown for affective response to PA as a determinant of future PA behavior among low active adults but assessed outside of the laboratory *via* EMA. Williams et al. (2016) instructed participants ($N$ = 59) to use a handheld device to indicate each time they were beginning a bout of PA over a 6-month period. Participants were then sent EMA prompts every 10-min while they completed the PA and then again 15-min post-PA termination. Small to medium effect sizes were observed for the association between affective response and the duration and latency of the next PA session. Liao et al. (2017a) used EMA to measure participants' ($N$ = 82) affect in response to PA when concurrent PA was also reported during a 4-day baseline period. These affect scores were then used to predict PA behavior, measured using accelerometry, 6- and 12-months later. The authors determined a 1-unit increase in positively valenced affect reported during concurrent PA was associated with an additional 4.62 min of PA per day 6-months later and an additional 5.24 min of PA per day 12-months later. Additionally, a 1-unit increase in negatively valenced affect reported during concurrent PA was associated with a decrease of 18.11 min of PA per day at 12-months, but the association between negatively valenced affect and PA at 6-months follow-up was not statistically significant.

In the Rhodes and Kates (2015) systematic review, nine studies were identified that examined post-PA affective response and future PA behavior (Berger and Owen, 1992; Klonoff et al., 1994; Annesi, 2002a,b, 2005; Schneider et al., 2009; Kwan and Bryan, 2010; Williams et al., 2012; Hargreaves and Stych, 2013). Again, there was significant variability among studies regarding covariates used (baseline affect and past behavior), sample characteristics (mixed PA experience background for adolescents and adults, sedentary adults, and new members to a fitness center) time of affect measurement, and type of affect measured. Here, only two of the nine studies found an association between immediate-post-PA affect and future PA (Berger and Owen, 1992; Annesi, 2005). Consistent with this general lack of positive findings, there was no association between post-PA affective response and future PA behavior in the EMA study conducted by Williams et al. (2016); post-PA affective response was not measured in the study by Liao et al. (2017a) discussed above.

The positive findings for during-PA affective response are consistent with psychological hedonism in that more positive (or less negative) affective responses during PA led to greater likelihood of future PA behavior. Interestingly, the hedonic principle, in its various incarnations, does not specify whether it is how one feels during or upon termination of the target behavior that is more likely to influence future behavior. However, the less robust findings for post-PA affective response are consistent with principles of operant conditioning in that more distal consequences of behavior (post-PA affective response) are less predictive of future behavior than more proximal consequences of behavior (during-PA affective response; see Williams, 2008).

A recent investigation, also conducted after the Rhodes and Kates (2015) review, sought to determine whether or not affective response to PA is a mechanism that can be improved (shifted more positively in valence) as a function of PA training volume completed over time and/or improvements in cardiorespiratory fitness (i.e., VO2max; Stevens et al., 2020). This line of research is predicated on past findings (from mostly cross-sectional study designs) that affective response to PA is more favorable among individuals who are more physically active and more physically fit (Parfitt et al., 1996; Reed et al., 1998; Bryan et al., 2007; Hallgren et al., 2010; Rose and Parfitt, 2012; Magnan et al., 2013; Frazao et al., 2016). Physically inactive participants ($N$ = 201) were randomly assigned to one of four exercise training conditions fully crossed on intensity (moderate and vigorous) and duration (short and long). Training occurred over 16-weeks and in-bout assessments of affective response (Feeling Scale; Hardy and Rejeski, 1989) and perceived exertion [measured using the Rating of Perceived Exertion (RPE) scale; Heath, 1998] were collected during weeks 1, 4, 8, and 16. Results showed that across conditions, affective response to exercise did not change, on average, over 16-weeks despite associated improvements in cardiorespiratory fitness. Conversely, RPE decreased slightly, on average, over time. Further, while baseline affective response scores were positively associated with exercise minutes at follow-up, consistent with Rhodes and Kates (2015), average affective response scores collected across the intervention were not associated with minutes of exercise at follow-up.

## Future Directions

Research in this area consistently shows a positive association between more positively valenced affective responses during PA and future PA behavior. From a translational perspective, the next steps in this line of research are to develop intervention strategies that can result in positive shifts in affective valence in response to PA. As discussed, reducing the intensity of PA is a reliable strategy for improving affective response (Ekkekakis et al., 2011). Building off of this evidence base, and further informed by findings that preference and autonomy in the selection of PA intensity positively impact affective response (Lind et al., 2008; Rose and Parfitt, 2008; Vazou-Ekkekakis and Ekkekakis, 2009; Williams and Raynor, 2013), a growing number of studies have tested "self-selected intensity" or "affect-regulated" approaches to PA promotion (Parfitt et al., 2006; Costa et al., 2015; Williams et al., 2015, 2016; Baldwin et al., 2016).

While traditional PA prescriptions instruct participants to regulate PA based on certain thresholds for intensity (e.g., % of $VO_2$max or % heart rate reserve; Garber et al., 2011), self-selected intensity PA prescriptions allow participants to choose their own intensity, whereas affect-regulated prescriptions explicitly instruct participants to choose an intensity that feels good (Zenko et al., 2017). Both self-selected intensity and affect-regulated prescriptions appear to yield more positive affective responses to PA (Parfitt et al., 2006; Lind et al., 2008; Williams et al., 2016) and greater PA engagement over time compared to traditional intensity-based PA prescriptions (Williams et al., 2015, 2016; Baldwin et al., 2016). Further, there is evidence that age and cardiorespiratory fitness moderate the effect of this approach on PA engagement such that it is most effective for individuals who are older and/or with lower cardiorespiratory fitness (Baldwin et al., 2016; Lee et al., 2020).

Another trend in this area of research is to conceptualize affective response to PA as a psychological or intermediate phenotype that mediates the effects of favorable PA genotypes on PA behavior (Bryan et al., 2017; Lee et al., 2018). This approach suggests that some individuals may be genetically predisposed to a more negative affective response to moderate-to-high intensity PA, whereas others may be predisposed to a more positive affective response. Rather than a more positively valenced affective response to PA resulting from higher activity levels/greater physical fitness – as the study by Stevens et al. (2020) explored and did not find evidence to support – certain individuals may be more drawn to PA (and thus become more physically fit) because they are genetically predisposed to a more positively valenced affective response to PA. Some individuals may possess this phenotype, but its expression could be masked or restricted due to the presence of other physiological factors known to influence affective response to PA such as

BMI or aerobic deconditioning. Alternatively, expression might not be realized due to social-environmental factors that limit opportunities for PA engagement. Although work exploring genetic underpinnings are limited, at least two studies have identified genetic variants associated with affective response to PA (Bryan et al., 2007; Karoly et al., 2012).

Conceptualizing the affective response to PA as an intermediate phenotype could have implications for designing more targeted PA interventions. For example, for those individuals who are predisposed to a negative affective response to PA, interventions that emphasize distraction (Lind et al., 2009; Blanchfield et al., 2014; Gillman and Bryan, 2016), habit formation (Kaushal et al., 2017; Rhodes and Gray, 2018; Rhodes and Rebar, 2018), and/or contextual and situational modifications (Dunton et al., 2015; Stevens et al., 2016; Zenko et al., 2016) may be more effective; conversely, for those who are predisposed to a more positive affective response to PA, a mindful approach to PA (Cox et al., 2017; Edwards and Loprinzi, 2019; Gillman and Bryan, 2020) and/or pre-PA expectation manipulations (Helfer et al., 2015; Kwan et al., 2017) may be more effective.

It is not yet known what effect regular practice of strategies like distraction, situational modification, or mindfulness might have over time on the affective response to PA. At present, the effects of affective-response-improving strategies have only been tested in single-session or limited session formats. Thus, it is not known if these strategies would continue to bolster affective response if used consistently over time or whether habituation effects may be observed. Also unknown is whether *combined use* of strategies could produce markedly greater improvement in affective response over use of individual strategies or whether affective response would return to a participant's baseline if strategies are not continued over time.

## INCIDENTAL AFFECT

Incidental affect refers to how one feels throughout the day. This type of affect is termed "incidental" because it occurs outside the context of the target behavior. Thus, incidental affect is not, like affective response, a direct result of the target behavior; however, incidental affect may influence engagement with the target behavior and/or be influenced by the target behavior (Williams and Evans, 2014). As with affective response, incidental affect constitutes affect *per se*; therefore, the same measures that can be used to measure affective response, for example, the Feeling Scale (Hardy and Rejeski, 1989), can be used to measure incidental affect. Incidental affect could be measured across the broad spectrum of affect as core affect, or as a specific affectively charged state, such as fatigue or anxiety, or as moods or emotions.

The majority of research evaluating the role of incidental affect as a determinant of health behaviors (beyond just the PA literature) has focused on how negative incidental affect influences behaviors that are harmful to health such as smoking, substance use, and binge eating (Williams and Evans, 2014). Two main theoretical perspectives – "affect regulation" and "affect congruency" theories – have informed much of the work in this area. As the name implies, "affect congruency" theories predict incidental affect will promote engagement with target behaviors that foster more similarly valenced affect, whereas "affect regulation" theories predict individuals will engage in behaviors that are expected to modify the current affective state.

With respect to negative incidental affect, affect regulation theories share conceptual overlap with principles of negative reinforcement (Williams and Evans, 2014) such that behavior is strengthened when associated with the removal or avoidance of an aversive stimulus (e.g., negative affect; Baker et al., 2004; Koob, 2013). This helps to explain why maladaptive behaviors (e.g., smoking, substance use, binge eating, and excessive sedentary time) are maintained even when they are incongruous with long term goal pursuits (e.g., smoking cessation, sobriety, weight loss, etc.) and/or no longer produce the same reward value (Tice et al., 2001; Volkow et al., 2010). In the context of PA, theories of affect congruence would predict that positive incidental affect is more likely to lead to PA behavior than negative incidental affect, whereas theories of affect regulation would predict that negative incidental affect may be more likely to lead to PA behavior if one expects that engaging in PA will produce a positive affective response.

### Negatively Valenced Incidental Affect

In terms of negatively valenced incidental affect preceding PA, both clinical and non-clinical populations report engaging in PA as an affect improvement strategy (Aldao and Dixon-Gordon, 2014; Jekauc and Brand, 2017) consistent with theories of affect regulation. Although, notably, among individuals with disordered eating pathology and/or high body image dissatisfaction, negative incidental affect often predicts PA engagement that is compulsory and performed despite illness or injuries (Goodwin et al., 2012b; Brownstone et al., 2013; Castonguay et al., 2017); thus, in such instances, PA may be functioning as an outlet for escaping negatively valenced affect more so than as an outlet for promoting positively valenced affect.

Outside the context of clinical populations, work in this area shows that incidental negatively valenced affect is associated with reduced likelihood PA will take place, consistent with affect congruency theories. A study conducted by Burg et al. (2017) used EMA methodology to measure affect (stress) experienced across the day as well as PA engagement over a 12-month period and found more stress experienced in the morning and/or previous evening resulted in 20–22% decreased odds of PA the subsequent day. Another recent EMA study conducted by Kerrigan et al. (2020) with participants enrolled in a behavioral weight loss trial found lower levels of negatively valenced affect and lower variability in negative affect, compared to one's baseline, predicted greater PA the following day. In contrast to these findings, a prior systematic review examining acute (within a few hours) relationships between PA and affect (experienced in non-laboratory settings) found no significant associations between negatively valenced incidental affect and subsequent PA (among the six studies meeting criteria for review at the time; Liao et al., 2015).

### Positively Valenced Incidental Affect

Positively valenced incidental affect is theorized to increase approach motivation and influence engagement with a number of health behaviors, including PA (Fredrickson, 2004; Lyubomirsky et al., 2005; Catellier and Yang, 2013; Kim et al., 2017; Rhodes et al., in press). In the majority of work regarding the relationship between positively valenced incidental affect and PA, positive associations have been observed across studies with heterogeneous participant samples and a wide variety of study designs/methodologies (Audrain et al., 2001; Carels et al., 2007; Schondube et al., 2016). The English Longitudinal Study on Aging, a study involving nearly 10,000 older adults found "psychological wellbeing" (a broad conceptualization of positively valenced affect) to be independently associated with greater PA participation over an 11-year period (Kim et al., 2017). Interestingly, higher baseline psychological wellbeing was associated with a slower rate of PA decline over the 11-year period among participants who were already physically active at baseline; among participants who were inactive at baseline, PA engagement increased over time.

An experimental study conducted by Cameron et al. (2018) demonstrated that positively valenced incidental affect can positively influence PA goal striving and attainment. Specifically, participants were randomly assigned to a positive affective valence (joy) induction condition or a neutral affective valence condition and then given the choice of participating in 20-min of PA (walking) or 20-min of a sedentary activity. The authors found more participants assigned to the positive affective valence condition (55.17%) than the neutral affective valence condition (36.67%) elected to participate in the 20-min walking task and performed more PA during the task.

In another recent study, Emerson et al. (2017) recruited a sample of ($N$ = 59) inactive, overweight/obese participants participating in a 6-month long PA intervention program and used EMA to collect multiple, random assessments of incidental affect and PA across the day for 29 consecutive days, and then again over 8-day segments 3- and 6-months into the PA intervention. Results demonstrated significant within-subjects cross-lagged effects: More positively valenced incidental affect at the start of a given day was associated with increased likelihood of PA later in the day (79% increased odds of PA associated with a 1 unit increase in affect assessed using the Feeling Scale; Hardy and Rejeski, 1989); and, after controlling for earlier incidental affect, PA participation was associated with more positively valenced post-PA incidental affect. The authors conclude that there is evidence of a reciprocal relationship between positively valenced affect and PA, but the strength of effect appears larger for the "affect-PA" pathway than the "PA-affect" pathway.

Using a similar methodological approach and analysis strategy, Liao et al. (2017b) found that results largely consistent with this those observed by Emerson et al. (2017). Specifically, the authors used EMA to measure participants' ($N$ = 110) incidental affect at eight random times throughout the day during a 4-day period and accelerometry to concurrently measure PA behavior. More positively valenced affect and less negatively valenced affect were positively associated with PA minutes completed over the subsequent 15 min and more PA was associated with more positively valenced affect over the subsequent 15 and 30 min.

### Future Directions

The findings summarized in this section suggest efforts to improve PA engagement may benefit from a focus on fostering more positively valenced incidental affect (and lower levels of negatively valenced affect) as well as potentially generating strategies for provoking "bumps" in positively valenced affect (especially at times across the day where affect may be vulnerable to negative shifts in valence). The proliferation of smartphone technology and methods, such as machine learning, hold significant promise regarding future opportunities for precision medicine in this area (Michie et al., 2017; Jacobson et al., 2019; Wilhelm et al., 2020). For instance, one could envision the development of a just-in-time intervention combining use of EMA and machine learning to anticipate participant behavior based on the micro-temporal associations between affect and PA (Nahum-Shani et al., 2016; Dunton et al., 2019).

Future work in this area will also need to address concerns regarding how to delineate post-PA affective response from post-PA incidental affect. Namely, how quickly does the acute affective response to PA dissipate and when is affect measured post-PA no longer considered influenced by the target behavior (and thus no longer considered affective response)? Are there individual differences regarding these phenomena? Do social, psychological, biological/physiological, or environmental characteristics moderate the speed of affective response dissipation or onset of incidental affective states? Can advances in sensor technology, EMA, and AI help to operationalize, capture, and differentiate between these affective states?

## AFFECT PROCESSING

Whereas the first two categories of affect-related constructs (i.e., affective response and incidental affect) represent affect proper, affect processing constructs reflect cognitive processing of previous affective responses (Williams and Evans, 2014). The category of affect processing includes affective associations, implicit attitudes, affective attitudes, affective judgments, anticipated affective response (AAR), and remembered affect. Affect processing factors are distinct from affective response as they can be prompted any time outside the context of the target behavior, whereas affective response to a behavior (and incidental affect) can only be experienced "*in vivo*."

Consistent with dual-process models, which posit that information about a stimulus or target is processed at two levels: one a quick, automatic, and intuitive level; the other a slower, deliberate, and reflective level (Smith and DeCoster, 2000; Evans, 2008; Kahneman, 2011; Reyna, 2012; Conroy and Berry, 2017; Brand and Ekkekakis, 2018) and affect processing constructs include both automatic (i.e., affective associations and implicit associations) and controlled processes (i.e., affective attitudes, anticipated affective response and remembered affect). Theoretically, in the reflective process, one first remembers their affective response, then anticipates a future affective response, and then forms an affective attitude. In the automatic process, memory and anticipation are automated and not separate steps – instead there are just affective associations that, in aggregate, lead to implicit attitudes. However, it is important to note that there is likely overlap between the two processing levels and corresponding affect processing constructs. For example, there is evidence that assessment of affective attitudes partly reflect implicit affective associations (Conner et al., 2011a).

## Affective Associations

Affective associations are defined as associations that exist in memory between PA and previously experienced affective responses to PA (Kiviniemi et al., 2007; Kiviniemi and Klasko-Foster, 2018). Although theoretically distinct from reflective affect processing constructs (Conroy and Berry, 2017), operationally, affective associations are assessed with self-report measures (e.g., “When I consider physical activity, I feel…”) that are quite similar to measures of affective attitudes (a reflective processing construct), in particular. As a result, the two factors may be difficult to distinguish empirically (Sala et al., 2016).

Research on affective associations as a determinant of PA is more limited than other affect processing factors. There is evidence that affective associations are associated with PA above and beyond known social cognitive predictors. In one study, Kiviniemi et al. (2007) asked healthy adults ($N = 433$) to report on various social cognitive beliefs relevant to PA, including their affective associations. Specifically, participants reported how they feel when considering PA (e.g., sorrow-joy) on three items. Participants also reported the number of vigorous PA minutes they engaged in per week. The results indicated that affective associations were significantly associated with vigorous PA minutes, after controlling for perceived benefits of PA, perceived barriers, social norms, and perceived behavioral control. In addition, a small pilot study ($N = 19$) tested the feasibility of targeting affective associations of PA *via* an evaluative conditioning approach delivered *via* smartphones (Conroy and Kim, 2020). Specially, positively-valenced PA images were installed as background on the phone lock screens to provide multiple daily exposures of the images to participants. This intervention approach resulted in increases in PA over 8 weeks (in a single group pre-post design), along with changes in several measures of PA-related affect, signaling this evaluative conditioning approach may be a promising way to target affective associations.

## Implicit Attitudes

Implicit attitudes are also defined as automatically triggered associations between two stimuli and are thus conceptually similar to affective associations. However, implicit attitudes are broader than affective associations in that implicit attitudes may or may not involve affect. Additionally, unlike affective associations, which are typically assessed *via* self-report, implicit attitudes are assessed *via* reaction-time tasks in which participants respond to PA-related word or image cues paired with affective descriptors (e.g., good-bad; see Conroy et al., 2010).

In a study of implicit attitudes and PA (Conroy et al., 2010), healthy young adults ($N = 201$) completed a reaction time-base implicit association test (IAT) to measure their implicit attitudes toward PA, along with other beliefs relevant to PA. They were given pedometers and their step counts were assessed over 1 week. Scores on the IAT predicted pedometer step counts above and beyond barrier self-efficacy and behavioral intentions. However, explicit measures of affective associations, or affective attitudes, were not included.

Taken together, evidence for the relationship between affective associations, or implicit attitudes, and PA is promising, but there is a need for additional evidence. Furthermore, there is need for future research to clarify whether implicit measures are capturing unique variance that is not captured in explicit measures of affective associations.

## Affective Judgments

Much of the research to date on affect processing factors involves affective attitudes and enjoyment. Affective attitudes are defined as evaluations of PA based on an aggregation of the likelihood and evaluation of affective outcomes of PA (e.g., the likelihood that PA will be enjoyable and how important that is to the respondent). This is in contrast to instrumental attitudes that are based on the same estimation of likelihood-evaluation but for instrumental outcomes (e.g., the likelihood that PA will reduce the risk of heart disease and how important that is to the respondent). While affective attitudes are theorized to be a function of separate likelihood and evaluation components, in direct assessment of affective attitudes respondents report the extent to which they evaluate PA using different affective descriptors (e.g., PA is enjoyable, boring, and pleasant). In the PA literature, the construct of PA enjoyment is most often operationalized and assessed with the Physical Activity Enjoyment Scale (PACES; Kendzierski and DeCarlo, 1991), a measure that is very similar in content to measures of affective attitudes in that it also prompts respondents to evaluate PA using different affective descriptors. Moreover, enjoyment has been examined jointly with affective attitudes in meta-analyses (Rhodes et al., 2009; Nasuti and Rhodes, 2013), under a broad umbrella term of affective judgments (Rhodes et al., 2019). For these reasons, we consider PA enjoyment in the same category as affective attitudes.

In the past 10 years, two meta-analyses conducted by Rhodes et al. (2009) have examined the association between “affective judgments” (i.e., affective attitudes and enjoyment) and PA behavior in adult samples and youth samples (ages 5–18; Nasuti and Rhodes, 2013). The meta-analysis on adult samples included 102 studies (114 independent samples) and the summary effect size was $r = 0.42$, a moderate sized effect and larger than effects reported in meta-analyses of the built environment (Duncan et al., 2005), socio-demographic (Bellows-Riecken and Rhodes, 2008), and personality (Bogg and Roberts, 2004; Rhodes and Smith, 2006) variables. The meta-analysis on youth samples (Nasuti and Rhodes, 2013) included 55 studies (70 independent samples), of which there were 15 experimental/intervention studies. The summary effect size for the correlational studies was $r = 0.26$ and for the experimental/intervention studies the effect size was $d = 0.25$, small-to-moderate effects. These effect sizes are smaller than in the meta-analysis with adult samples, perhaps due to PA behavior being more of a volitional behavior in adulthood compared to childhood and adolescence. In sum, the two meta-analyses on affective attitudes provide robust evidence that these factors are important correlates and determinants of PA behavior.

Interventions that target affective attitudes can be effective in influencing PA. Conner et al. (2011b) conducted two studies with young adult samples ($N = 383$ and $N = 197$) in which participants were randomized to read messages focused on (a) the affective benefits of exercise (e.g., it can reduce anxiety, depression, and stress) or (b) the instrumental benefits of exercise (e.g., it can prevent cancer and build healthy muscles and joints). There was also a no-message control condition. In both studies, the affective benefits message resulted in more exercise sessions over a 3-week period than the instrumental benefits message or no message control. Results from both studies also indicated that the intervention effect was partially explained by changes in affective attitudes. Additional findings suggested that the message intervention was more effective for individuals who tend to rely on emotion in decision-making (i.e., need for affect) and less effective for those who have a high need to think and deliberate on problems (i.e., need for cognition). Overall, the findings from these two experimental studies provide compelling evidence that intervening to focus people's thinking and attention on affective aspects of exercise can more effectively influence exercise behavior than focusing on the instrumental aspects of exercise.

## Anticipated Affective Response

Anticipated affective response (AAR) is defined as the expectation of how one will feel in response to engaging in, or failing to engage in, PA. Conceptually, it is a type of outcome expectation, a construct found in most expectancy-value theories of health behavior (e.g., Health Belief Model, Social Cognitive Theory, and Theory of Planned Behavior). In the PA literature, short-term AAR has typically been assessed immediately prior to an exercise bout, with longer-term AAR assessed as anticipated affect in response to hypothetical future PA.

Studies examining short-term AAR have consistently demonstrated that AAR is positively associated with actual affective response during or shortly after the exercise bout (Ruby et al., 2011; Loehr and Baldwin, 2014; Helfer et al., 2015; Kwan et al., 2017). Two studies demonstrated this effect experimentally by manipulating what participants were told the exercise session they were about to complete would feel like, e.g., "most people report this activity feels good" and "most people report this activity does not feel very good" (Helfer et al., 2015; Kwan et al., 2017). Another consistent finding across these studies is that short-term AARs tend to underestimate how positive or pleasant the exercise will actually be (i.e., affective forecasting bias; see Ruby et al., 2011; Loehr and Baldwin, 2014), and this bias may be even larger among physically inactive individuals (Loehr and Baldwin, 2014). Despite the consistent effects AARs have on affective response during an exercise bout, it is important to note that the manipulation of anticipated affect did not have an effect on future PA behavior in the two experimental studies (Helfer et al., 2015; Kwan et al., 2017).

There is, however, stronger support for the effects of longer-term AARs on future PA behavior. Dunton and Vaughan (2008) asked participants to report their positive AARs (delighted, happy, fulfilled, calm, relaxed, and at ease) if they successfully engaged in regular PA over the subsequent 90 days, and their negative AARs (sad, dissatisfied, distressed, nervous, tense, and anxious) if they failed to engage in regular PA. Participants also reported their PA behavior at baseline and at 90 days follow-up. For those who were physically inactive at baseline, positive AAR but not negative AAR predicted those who were likely to adopt regular PA compared to those who stayed inactive. For those who were already physically active at baseline, the same pattern emerged in predicting the likelihood of maintaining PA over the 90 days. In sum, anticipated positive AARs associated with success were stronger predictor of future PA than anticipated negative AARs associated with failure.

Studies on anticipated regret as an AAR to failure to engage in future regular PA (Abraham and Sheeran, 2003, 2004) have demonstrated that anticipated regret influences future PA. Anticipated regret also positively influences the formation of PA intentions and explains unique variance in intentions not explained by past behavior or other social cognitive variables found in the Theory of Planned Behavior (Ajzen, 1991).

## Remembered Affect

Remembered affect is defined as the recall of the affective response during previous PA. Conceptually, remembered affect is distinct from affective response in that it is the *recall* of how one felt during a PA bout, whereas affective response is how one feels *while* engaging in PA. Remembered affect is also distinct from other affective processing factors in that it reflects cognitive processing of a specific PA bout rather than an aggregate evaluation of previous affective responses. Although there are limited data to date, the theoretical rationale for the importance of remembered affect on PA behavior is compelling. Specifically, Kahneman et al. (1993) have argued that it is our memories of affective response, rather than affective response *per se*, that determines whether we will be motivated to perform the behavior in the future (i.e., "remembered utility"; see Redelmeier et al., 2003).

Reports of remembered affect may be different than reports of experienced affective response as memory is prone to biases and often does not align with what was actually experienced (Broderick et al., 2008; Giske et al., 2010). For example, memory can be biased by cognitive heuristics, such as the peak-end rule (Kahneman et al., 1993), which suggests that memory is weighted more heavily toward affective experiences (e.g., affective response during exercise) that reflect the most intense (i.e., peak) and the end of the total experience.

Indeed, there is some evidence that remembered affect may deviate from actual affective response. Zenko et al. (2016) randomized participants to complete an exercise bout with either increasing or decreasing intensity. Ending an exercise bout more pleasantly than it began had a strong and enduring effect on how positively the bout was remembered 15 min, 24 h, and 7 days later. However, the effect of remembered affect on future PA was not examined. In a study described earlier by (Kwan et al., 2017) in which participants' AARs were manipulated prior to an exercise bout, participants also reported their remembered affect following the exercise bout ("How do you remember feeling while exercising today?") and were instructed to exercise every day for the upcoming week. Remembered affect was the only significant predictor of exercising all 7 days. Anticipated and experienced affective response during the bout did not predict PA. In terms of influencing PA behavior, remembered affect is a promising factor given evidence that people tend to base their deliberate decision-making about future behavior more on how they remember/recall their affective experiences rather the actual affective experiences (Kahneman et al., 1993; Redelmeier et al., 2003).

### Future Directions

An important future direction regarding affect processing factors is to clarify the inter-relations among affect processing variables, affective response, and behavior. Doing so would have important implications both for advancing understanding of their interrelations and for developing and refining novel interventions that can target these factors. The relations between affect processing factors and affective response are certainly reciprocal. AAR influences affective response during PA (at least when PA is performed at intensities below the VT), and affective response during PA influences how the PA is remembered and evaluated. While affective response during PA is theoretically the primary source of variance for the various affect processing variables, processed affect may also be dependent on other factors (environmental and social) that are tangential to the PA affect response (Rhodes et al., 2019). Further, it is not clear whether the effect of affective response during exercise on subsequent PA is mediated by remembered affect or another affective processing factor (e.g., affective attitudes and affective associations). If so, it would raise the possibility that interventions designed to target both affective response and the subsequent affect processing factor would be most effective.

A second future research direction in this domain is to clarify the extent to which measures of the different affect processing factors are measuring the same or different constructs (i.e., their construct validity) and whether they can be independently manipulated. Recent data suggest that there is a high degree of empirical overlap among the prevalent measures of affect processing factors (Chmielewski et al., 2016; Sala et al., 2016) and some of the measures have significant construct validity limitations. Addressing the construct validity of affect processing measures can clarify theoretical and empirical distinctions among the constructs (e.g., affective attitudes and enjoyment) and will improve the precision and reliability with which the constructs are assessed, which will also impact the design of interventions intended to modify them.

## AFFECTIVELY CHARGED MOTIVATION

As defined by the AHBF, affectively charged motivation for PA includes motivational states that have their basis in past affective responses to PA, such as craving, desire, dread, intrinsic motivation, and fear (Williams and Evans, 2014). Affectively charged motivation constructs differ from reflective motivation constructs, such as intentions and goals, which are a function of more deliberate consideration of the potential outcomes of a behavior. Consistent with the emphasis herein on affective determinants of PA, this section provides an overview of affectively-charged motivation to the exclusion of reflective motivation.

In the PA literature, intrinsic motivation, which has largely been studied in the context of Self-Determination Theory (SDT; Ryan and Deci, 2007), has received the most attention from among the affectively charged motivational states. A construct closely related to fear, anxiety sensitivity, also fits within the broad category of affectively charged motivation and will also be reviewed in this section. Finally, craving, desire, and dread collectively represent "hedonic motivation," which has not yet received broad empirical support as an affective determinant of PA, but is likely to be important for understanding PA behavior (Williams, 2018, 2019; Williams and Connell Bohlen, 2019).

### Intrinsic Motivation

As posited in SDT, intrinsic motivation is the propensity to seek out pleasure, novelty, aesthetics, and spontaneous interest – it is motivation to perform a behavior or action for the inherent enjoyment that doing so provides (Ryan and Deci, 2000a). Intrinsic motivation for PA is often assessed with the Intrinsic Motivation Inventory (Mcauley et al., 1989) which asks respondents to rate their agreement with items such as, "I enjoyed this activity very much," "this activity was fun to do," and "I thought this activity was quite enjoyable." Likewise, the Behavioral Regulations in Exercise Questionnaire (Mullan et al., 1997) includes items, such as "I get pleasure and satisfaction from participating in exercise," "I exercise because it is fun," and "I find exercise a pleasurable activity." In contrast, extrinsic motivation is the propensity to perform a behavior or action in order to obtain external rewards or desirable outcomes (Ryan and Deci, 2000a). For example, being motivated to perform the same actions because one expects the experience will result in weight loss or improved social status. In this case, such an outcome may cause a person to feel good, but the motivation to perform the behavior is driven by the expected results of the behavior, not the experience of the behavior itself. Thus, intrinsic motivation pertains to the pursuit of affective outcomes of behavior whereas extrinsic motivation pertains to the pursuit of instrumental outcomes of behavior (Williams and Evans, 2014). Notably, because measures of intrinsic motivation necessarily ask respondents to rate their enjoyment of PA, some have argued that these scales unintentionally assess a construct that is essentially PA enjoyment (Rhodes et al., 2019); however, in theory, intrinsic motivation is a separate construct from PA enjoyment.

According to SDT, intrinsic motivation is the most autonomous form of motivation and is a driver of behavioral persistence. Consistent with this prediction, the overwhelming majority of evidence suggests that intrinsic motivation plays an important role in PA behavior and especially maintenance of PA behavior over time (Hagger and Chatzisarantis, 2007; Ryan and Deci, 2007; Standage et al., 2008; Wilson et al., 2008; Teixeira et al., 2012). As might be expected, individuals who engage in PA more frequently report stronger intrinsic motivation for PA (Teixeira et al., 2012), but inactive individuals have the capacity to develop increased intrinsic motivation for PA over time (Rodgers et al., 2010). As described by the Multi-Process Action Control Framework (Rhodes, 2017), increased exposure to PA and increased intrinsic motivation for PA lead to a stronger sense of self as "an exerciser" and this exercise identity promotes PA maintenance as PA behaviors become integrated into one's daily routine (Gillman et al., 2017).

Consistent with the conceptualization of intrinsic motivation as the pursuit of affective outcomes of behavior, a study by Schneider and Kwan (2013) found that affective response to acute bouts of PA positively predicted intrinsic motivation for PA among a sample of adolescents. In another study, Schneider (2018) showed that intrinsic motivation mediated the relationship between affective response to an acute bout of PA and PA levels at baseline (cross-sectionally) and 5-months follow-up. Related research has shown that focusing on the proximal outcomes of PA, such as improved feelings states, may generate more intrinsic motivation for PA than focusing on distal outcomes (which are inherently extrinsically oriented), such as improved health (Evans et al., 2014).

## Fear and Anxiety Sensitivity

Fear is an emotion that motivates movement away from behaviors that have previously been associated with immediate negatively valenced affect (displeasure). For example, if past experiences of PA have been unpleasant or aversive, fear of experiencing those affective states again would motivate one to avoid PA. However, in rare circumstances, fear motivates PA as a means to an end (e.g., running away from something dangerous). While fear has received little attention with respect to its relationship to PA, anxiety sensitivity, sometimes referred to as "fear of fear" (Craske and Barlow, 2014), has been more thoroughly investigated.

Anxiety sensitivity is the fear of somatic arousal-related sensations commonly experienced when one is experiencing anxiety or panic, for instance increased heart rate, labored respiration, muscle tension, and sweating, because of a misappraisal of these somatic sensations as dangerous (Reiss and McNally, 1985). Anxiety sensitivity is one factor that may contribute to poor tolerance of negative affect/displeasure during PA, and ultimately, avoidance of PA (Smits et al., 2010; Sabourin et al., 2011; Moshier et al., 2013, 2016; Hearon et al., 2014).

Predictably, there is an observed inverse relationship between anxiety sensitivity and PA engagement. For instance, Moshier et al. (2016) found that anxiety sensitivity, measured using the Anxiety Sensitivity Index, a 16-item self-report measure including items such as "it scares me when I feel faint," prospectively predicted PA engagement (negatively) over and above the effect of past PA behavior among a sample of college students who self-identified as being motivated to increase their PA participation. Interestingly, other theory-informed self-regulatory constructs, such as goal setting, action planning, and perceived behavioral control, were not predictive of PA at follow-up controlling for past PA. Although this study was conducted with a sample of young and healthy college students, the authors argue that the findings underscore the importance of examining affective factors, in this case anxiety sensitivity, with respect to the PA intention-behavior gap (Sheeran and Webb, 2016). In a prior study, Moshier et al. (2013) found a negative cross-sectional association between anxiety sensitivity and participation in vigorous intensity PA but no association between anxiety sensitivity and moderate intensity PA.

Others have extended this research to understand the role of anxiety sensitivity among individuals higher on BMI who have been shown to have a more negative affective response to PA (Ekkekakis and Lind, 2006). In a study by Smits et al. (2010), participants with various BMIs and levels of anxiety sensitivity were randomly assigned to 20 min of treadmill running at 70% of their age-adjusted predicted maximum heart rate or 20 min of rest; for both conditions, perceived distress measures were collected every 4 min. The researchers observed a significant condition by BMI by anxiety sensitivity interaction suggesting that higher levels of distress were experienced among participants higher on BMI, but only if they were also high on anxiety sensitivity (Smits et al., 2010). Similarly, Hearon et al. (2014) found that high anxiety sensitivity was associated with less engagement in moderate intensity PA over the course of 1 week for high BMI participants, but the inverse was true for participants with a BMI in the normal weight range.

One mechanism through which anxiety sensitivity may influence PA is through overestimation of PA intensity. For example, one recent study found participants with panic disorder reported significantly higher perceived exertion (measured as RPE; Heath, 1998) in response to PA during an exercise stress test compared to a group of healthy controls (not meeting clinical criteria for panic disorder) matched on age, BMI, and activity level (Muotri et al., 2017). Among the control participants, there was a clear positive correlation between RPE scores and percent of max heart rate, as is commonly reported in the literature, but among participants with panic disorder there was no such relationship. Further, participants with panic disorder achieved lower peak oxygen consumption ($VO_2$max) scores during the exercise stress test compared to controls despite there being no differences between groups on activity level prior to exercise testing (all participants were predominantly sedentary). The authors speculate that participants with panic disorder are unwilling to push themselves to the point of exhaustion during testing due to poor tolerance of their autonomic experience (i.e., anxiety sensitivity; Muotri et al., 2017).

## Hedonic Motivation

The recently introduced concept of hedonic motivation is posited as the mechanism through which past affective experiences influence future behavior, consistent with the ancient and intuitive principle of psychological hedonism (Williams, 2018, 2019). Through the process of associative learning, behaviors that elicit immediate affectively favorable responses (e.g., pleasure or relief from displeasure) tend to become targets of hedonically driven craving/desire, whereas behaviors that elicit affectively unfavorable responses (e.g., displeasure) tend to become targets of hedonically driven dread, with hedonic craving/desire and hedonic dread representing opposite poles of hedonic motivation. Importantly, though experienced consciously, hedonic motivation is produced automatically without deliberate cognitive or affect processing regarding how the target behavior is expected to feel (AAR), how it was experienced previously (remembered affective response), or how performing the behavior may yield future costs or benefits (Williams, 2018, 2019). Consistent with incentive salience theory (Berridge and Robinson, 2003; Berridge, 2007), hedonic motivation and affective response are propagated by separate neurobiological pathways and feature distinct psychological characteristics (Williams, 2018, 2019). For instance, while the experience of pleasure is positively valenced, the experience of craving/desire may or may not be associated with positive valance; rather, craving/desire may be experienced as negative in valence, especially if the target behavior is unavailable (e.g., no desserts to eat in the immediate environment) or inconsistent with one's goals or values (e.g., weight loss; Williams, 2018, 2019).

In the context of PA research, hedonic dread is more relevant than hedonic craving/desire because the public health problem related to PA is that people do not engage in enough of the behavior, rather than engaging in too much of the behavior (e.g., eating, smoking, alcohol and drug use, and risky sexual behavior). Hedonic dread of PA refers to the automatic subjective experience of not wanting to engage in PA and is a function of prior experiences of displeasure or discomfort during PA (Williams and Connell Bohlen, 2019). For many individuals who may stand to benefit greatly from increased amounts of PA, specifically those who are more overweight, sedentary, at risk for chronic illness, or living with chronic illness, affective response to PA is negative in valence, especially at more vigorous levels of intensity (Ekkekakis and Lind, 2006; Ekkekakis et al., 2011). While there is now a substantial literature on affective response to PA, there is, as yet, no research on the hedonic dread that represents the proximal linkage between previous negative affective response to PA and future avoidance of PA behavior. The concept of hedonic dread, in combination with the burgeoning research based on negative affective response to PA, provides a compelling rationale for why PA is a behavior that, despite providing extensive of health benefits, is plagued by poor adherence and drop out (National Center for Health Statistics, 2018).

Hedonic craving/desire is, in the context of PA, most relevant for research on pathological dependence on PA. Both craving and desire refer to the automatic subjective experience of wanting to perform a behavior. "Exercise dependence" has been defined in terms of "craving" for exercise that is excessive and intractable despite compromised health, wellbeing, and/or social and occupational role functioning (Hausenblas and Downs, 2002; Chen, 2016; Macfarlane et al., 2016; Lichtenstein et al., 2017; Marques et al., 2019). Exercise dependence is not a common condition; approximately 0.5% of the general adult population are believed to meet criteria (Chen, 2016), but a study by Lichtenstein and Jensen (2016) found that the prevalence among CrossFit participants (a high intensity strength and conditioning fitness program) may be as high as 5%. Although exercise dependence and other similar terms (e.g., "exercise addiction," "obligatory exercise," and "excessive exercise") are defined by the presence of intense "craving/desire" for exercise, little to no research has been conducted to directly measure craving/desire for PA. Rather, much of this literature focuses on the measurement of exercise dependence and the relationship of the construct to other diagnostic or personality characteristics (Hausenblas and Downs, 2002; Hausenblas and Fallon, 2002; Hausenblas and Giacobbi, 2004; De Young and Anderson, 2010; Paradis et al., 2013; Holland et al., 2014; Hill et al., 2015).

## Future Directions

According to the AHBF, affectively charged motivational states are posited to be the mechanism through which prior affective response to PA influence future PA. However, research testing this causal pathway is needed. Likewise, the AHBF suggests that affect processing constructs also influence hedonically charged motivational states, and thus, future work might explore whether the pathway from affective response to affectively charged motivation is mediated by affect processing constructs. Future work may also explore whether efforts to influence affectively charged motivational states are more effective if they do so by targeting affective response and affect processing factors simultaneously or separately.

Research on increasing intrinsic motivation for PA has begun to emphasize mindfulness techniques (Gardner and Moore, 2012). The notion that persons are motivated to pursue actions and activities, such as PA, that assist them in living a values-aligned life is a central tenant of acceptance-based approaches and is very near in concept to intrinsic motivation (Ryan and Deci, 2000b, 2007; Teixeira et al., 2012). According to practitioners of acceptance-based approaches, by leveraging the desire to live a values-aligned life and drawing out discrepancies between aspirations and actions (for instance, an individual who reports valuing her longevity, vitality, and/or ability to function independently into older age but is being unwilling to engage in PA due to associated unpleasant feelings), it may be possible to build self-identification with PA and increase intrinsic motivation for PA (Stevens and Bryan, 2015). Likewise, the concept of exposing oneself to different – potentially aversive – experiences and experiential contexts (e.g., the presence of uncomfortable feelings or sensations such as muscle cramping or shortness of breath during PA) is also an integral component of acceptance-based therapies and behavioral interventions. Acceptance-based approaches promote the development of mindful awareness and psychological acceptance skills that may increase willingness to experience and tolerate discomfort during PA (Stevens and Bryan, 2015), and indeed, evidence suggests that acceptance-based interventions show promise for increasing PA behavior (Ulmer et al., 2010; Butryn et al., 2011, 2018; Goodwin et al., 2012a; Kangasniemi et al., 2015; Pears and Sutton, 2020).

Finally, efforts to mitigate the effects of anxiety sensitivity on PA behavior may be informed by empirically supported treatments for anxiety and panic. For example, interoceptive exposure is a technique included in cognitive behavioral treatment approaches for anxiety that is used to help individuals stop avoiding behaviors or situations that elicit arousal symptoms (i.e., symptoms of a panic attack), such as climbing stairs, or jogging (Craske and Barlow, 2014). Interoceptive exposure works by repeatedly and purposefully eliciting arousal symptoms (i.e., sweating, elevated heart rate, and breathing rate) that are harmless, but feared, in a therapeutic context where escape/avoidance behavior can be mitigated. When treatment is successful, the individual learns through the exposure process that those symptoms are not actually dangerous and the fear response is extinguished. Some research has shown that PA can serve as the interoceptive exposure intervention to reduce anxiety sensitivity (Broman-Fulks et al., 2004; Broman-Fulks and Storey, 2008). Therefore, intervention work in the PA literature may be able to reduce avoidance of PA *via* "exposure" training sessions that help participants to experience somatic symptoms without terminating the activity.

## SUMMARY AND CONCLUSIONS

This conceptual review covered examples of affect-related correlates and determinants of PA in each of the four areas outlined by the AHBF: affective response to PA, incidental affect, affect processing, and affectively charged motivation. The majority of research concerning affect-related correlates and determinants of PA has been done in the areas of affective response and affect processing. The literature on incidental affect is smaller but growing. Less work has explicitly focused on affectively charged motivational states as correlates and determinants of PA, with the bulk of research in that area on the concept of intrinsic motivation.

Within each of the four AHBF categories, there is considerable heterogeneity in terminology, conceptualization, and assessment. This heterogeneity can lead to confusion and misinterpretation of research findings. For example, inconsistent use of the terms "positive affect" and "negative affect" as either labels for the dimensions of Watson and Tellegen's (1985) the rotated circumplex model or as labels for positive vs. negative valence has led to considerable confusion in the literature (Ekkekakis, 2013). As research on affective determinants of PA evolves, researchers should strive to use terminology and conceptualizations for affect-related constructs that clearly delineate the constructs under study and distinguish them from related, but distinct constructs.

As a corollary to the latter point, more research is needed that examines the empirical distinction among different affect-related constructs, how they differentially predict and combine to predict PA behavior. In addition to prediction of PA, research is needed to elucidate the pathways through which different affect-related constructs inter-relate to influence PA behavior. Such research requires experimental designs and multiple assessments with appropriate temporal ordering of constructs to model potential causal pathways.

While the present paper has focused on affect-related factors, as highlighted in the AHBF, research is also needed that examines how affect-related (reviewed herein) and traditional cognitive factors (e.g., instrumental outcome expectancies and attitudes, social norms, self-efficacy, and behavioral intentions) interrelate to influence PA behavior. For example, when will affective factors matter most, and when will cognitive factors matter most? One possibility is that affective factors are central to determining motivation for PA, but specific plans and strategies are important for executing the behavior, with these affective and cognitive processes interacting on a daily basis. This idea is, however, merely conjecture at this point, as more research is needed.

Ultimately, what is needed is translation of the accumulating basic science findings on affect-related determinants of PA into targeted interventions to promote PA. For example, research is needed that identifies multiple strategies for influencing each type of affect category and then identifies which strategy or which combination of strategies is most effective at influencing the target affect category. Interventions could then be developed to target multiple levels of the AHBF and/or see how an intervention targeting one level of the ABHF "spreads" to other areas. For example, an evaluative conditioning intervention intended to impact affect processing may additionally show impact on affective response and/or affectively charged motivational states.

This review has highlighted – in the context of the AHBF – the many affect-related constructs that have been conceptualized and studied as putative determinants of PA behavior. As with cognitive constructs that have been studied over the past several decades, these affect-related constructs require in-depth research to understand the many ways in which they inter-relate to influence PA.

## AUTHOR CONTRIBUTIONS

CJS and DMW conceptualized and drafted most of the manuscript, and finalized the manuscript. ASB, ADB, MC, and RER contributed subsections and provided feedback on the full manuscript. All authors contributed to the article and approved the submitted version.

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# Self-Distancing as a Strategy to Regulate Affect and Aggressive Behavior in Athletes: An Experimental Approach to Explore Emotion Regulation in the Laboratory

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Self-regulation, especially the regulation of emotion, is an important component of athletic performance. In our study, we tested the effect of a self-distancing strategy on athletes' performance in an aggression-inducing experimental task in the laboratory. To this end, we modified an established paradigm of interpersonal provocation [Taylor Aggression Paradigm (TAP)], which has the potential to complement field studies in order to increase our understanding of effective emotion regulation of athletes in critical situations in competitions. In our experimental setting, we first tested the applicability of the self-distancing perspective and the athletes' ability to dynamically adapt besides the self-distanced perspective a self-immersed perspective to provocation in the TAP. Secondly, we investigated how this altered perspective modulated regulatory abilities of negative affectivity, anger, and aggression. The experiment consisted of two conditions in which the participant adopted either a self-immersed or a self-distanced perspective. Forty athletes (female: 23; male: 17) from different team (*n* = 27) and individual sports (*n* = 13) with a mean age of 23.83 years (*SD* = 3.41) competed individually in a reaction-time task against a (fictitious) opponent. Results show that athletes are equally able to adopt both perspectives. In addition, within-person analyses indicate that self-distancing decreased aggressive behavior and negative affect compared to the self-immersed perspective. Our results suggest that self-distancing modulates different levels of athletes' experience (i.e., affect and anger) and behavior. Furthermore, this demonstrates the feasibility of testing self-regulation of emotion in athletes in a laboratory setting and allows for further application in research in sports and exercise psychology.

**Keywords: self-distancing, experimental design, competitive athletes, provocation, anger, self-regulation, negative affect, competitive context**

## INTRODUCTION

The present study aims at testing the effect of a self-distancing strategy for the regulation of emotion (i.e., combined verbal and visual self-distancing technique) in a group of competitive athletes in a laboratory setting. The background of this study is two-fold. First, the implementation of effective and easy-to-apply emotion regulation strategies is a relevant research question especially in the context of provocative or aggressive behavior (e.g., by an opponent) where a lack of self-control can have detrimental consequences in the unforgiving environment of a sports competition (see e.g., Ring et al., 2019). For instance, situations in which athletes are charged with emotions (e.g., an incomprehensible referee decision after a foul, mockery, or insult from an opponent) may trigger unfair behavior, which may lead to disqualification, or exclusion from (further) competitions in turn. Second, understanding the efficacy of emotion regulation strategies for competitive athletes demands a multi-level research strategy: On the one hand, the effect of emotion regulation has to be studied in the context of real-world sports-relevant situations, for instance, by correlating individual emotion regulation competence with athletes' performance in competitions. However, field studies have the disadvantage that they are time-consuming and costly. In addition, due to the complexity of the situation it might be difficult to identify which aspect of the emotion regulation strategy was finally effective. On the other hand, using laboratory tasks allows for a more detailed and systematic investigation of the effective feature of an emotion regulation strategy; moreover, it is easier to replicate these findings and to apply those to different groups of participants (e.g., youth athletes at different stages of their career). In contrast, effects observed in laboratory setting usually lack ecological validity (i.e., due to the simplified situation and the focused manipulations in an experiment), which limits the generalizability of findings to everyday-life situations. Therefore, field studies and laboratory studies can complement each other in fostering our understanding of effective emotion regulation in athletes. Such an approach requires the development and application of laboratory tasks for investigating emotion regulation in athletes. Here we present the application of an established laboratory task [the Taylor Aggression Paradigm (TAP); Taylor, 1967] within an experimental setting in which the participants adopted a self-immersed and a self-distanced perspective. With this procedure, we tested emotional responses to a provocation by a (virtual) opponent on different levels (i.e., affect, anger, and aggressive behavior) and determined a potential effect of the self-distancing on the related measures.

The ability of athletes to regulate their emotions is regarded by many sports psychologists as an important psychological skill (e.g., Thomas et al., 1999; Karageorghis and Terry, 2011; Crocker et al., 2015). One conceptual approach to the regulation of emotions is provided by the cognitive-motivational-relational (CMR) theory by Lazarus (2000a,b). The CMR theory proposes that specific emotions underlie a core relational theme that describes the interaction between the athlete and his or her environment (Lazarus, 2000a,b). The individual evaluation (*appraisal*) of the personal significance of a specific situation (e.g., actions by an opponent or a referee) makes each emotion unique and at the same time impedes the endeavor to determine which emotions are the most relevant for any given individual in a competitive context (Lazarus, 2000b). In our study, we focused among others on the subjective experiences of anger, which underlies the core relational theme "a demeaning offense against me and mine" (Lazarus, 2000b, p. 234) and can be followed by a "powerful impulse to counterattack in order to gain revenge for an affront or repair a wounded self-esteem" (Lazarus, 2000a, p.56; Lazarus, 2000b, p. 243). A frequent trigger for the appearance of anger are actions that are judged aversive, such as provocation. Team sports, where interaction and physical contact among opponents are unavoidable, provide many opportunities for provocation and as a result, can lead to negative affectivity and/or reactive aggression (Maxwell, 2004). It is therefore even more important that athletes are able to regulate their emotions, stay concentrated, and avoid intrusions of goals and thoughts that are irrelevant of the ongoing athletic performance (Lazarus, 2000b). Importantly, CMR theory provided a framework for the development of emotion regulation strategies (see Jones, 2003; Uphill et al., 2009). One likely candidate, which has not yet received much attention in the sports context but fulfills these requirements, is self-distancing.

People naturally adopt a first-person perspective (or self-immersed perspective, e.g., "Why am I so angry?"; Kross and Ayduk, 2008) when they process intense emotions. They often replay past anger-inducing situations without resolving them, thus down-spiraling into rumination and negative affectivity (Denson et al., 2011; Denson, 2013). This approach often backfires, perpetuating negative thoughts and feelings rather than improving the way people feel (Mischkowski et al., 2012). In contrast, self-distancing describes the ability to reflect adaptively on negative experiences. The strategy can be applied in two ways: (1) by engaging in a visual shift and evaluating one's affective experience from an external observer's point of view or (2) by engaging in a linguistic shift by using third-person self-talk (Kross and Ayduk, 2017). Both strategies would change the situation-related thoughts about oneself from "Why am I so angry?" to "Why is he/she so angry?" (but note that the person is thinking about himself/herself in both perspectives). Previous studies showed that self-distancing compared to self-immersion results in less negative emotions (for an overview see Kross and Ayduk, 2017), less anger (Kross et al., 2005) as well as less physiological distress (Ayduk and Kross, 2008, 2010). Moreover, Mischkowski et al. (2012) demonstrated that taking a self-distanced perspective in the heat of the moment reduces aggressive thoughts, angry feelings, and aggressive behavior. Streamer et al. (2017) showed that self-distancing also leads to a positively rated experience in active performance stressors without altering the self-rated relevance of the task. Results from another study (Leitner et al., 2017) indicated that self-distancing improved interpersonal perceptions and behavior by decreasing self-referential processing during the provision of criticism. Moreover, Kross and Ayduk (2017) highlighted the everyday life application of self-talk manipulation for helping individuals to cope effectively with stressors. Finally, further studies (Kross et al., 2005; Kross and Ayduk, 2009; Pfeiler et al., 2017) stressed that especially high-affect individuals could profit of self-distancing because it may be helpful to enable self-control. Taken together, these findings provide evidence that self-distancing supports people in their attempts to cope with negative experiences.

In the context of sports, experimental studies on perspective taking are rare so far. Typically, correlational studies focused on perspective taking in form of empathy or distancing as coping strategy. With regard to the former, research has focused on relations between empathy and antisocial behavior, negative emotions as well as moral disengagement (Kavussanu et al., 2015; Stanger et al., 2017, 2018). Moreover, several coping questionnaires were used to measure distancing in relation to achievement motivation and affect (Ntoumanis et al., 1999), mental toughness, optimism, and pessimism (Nicholls et al., 2008), or defense mechanisms (Nicolas and Jebrane, 2008). However, distancing was measured each time as an avoidance strategy like mental distraction. Lastly, a qualitative analysis with Olympic wrestlers identified perspective taking as a kind of rational thinking strategy to control thoughts during competitions (Gould et al., 1993). In contrast, Stanger et al. (2012, 2016) performed experimental studies and applied the TAP to investigate under which conditions empathy modulates aggression in athletes. These studies demonstrated that the TAP is a well-established laboratory measure also for athletes. For this reason, the TAP is the measure of choice for our study.

In the present study, participants performed the TAP either under a self-distanced or under a self-immersed condition as introduced by Kross et al. (2014). We aimed at testing whether the application of self-distancing in the context of the TAP was feasible and whether participants (competitive athletes in particular) were able to adapt the two different perspectives. To examine whether the two instructions were successfully implemented, we tested the effect of the manipulation in two ways: First, we analyzed self-reports of perspective taking (i.e., ratings of how well participants were able to adapt the respective perspective). Second, we employed a linguistic approach, and counted the amount of first and third-person pronouns in the short essays produced in the writing task during the respective perspective manipulation (see details below). Rating data and word counts of first- and third-person pronouns allow to evaluate whether athletes are equally well able to adapt both perspectives. In addition to that, we were also interested in whether self-distancing has an effect on different levels of emotional experience and behavioral responses. With regard to the effect of the two perspectives on affectivity, we expect the following outcome: In the self-immersed condition, athletes report higher levels of negative affect [as captured by the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)] after completing the TAP relative to the self-distanced condition (*Hypothesis 1*). Because our study was designed to specifically induce anger, we computed additional analyses with an anger index suggested by Watson et al. (1988; see also Kross et al., 2005) and tested differences between a self-distanced and a self-immersed condition. The main outcome measure relative to the TAP is aggressive behavior after provocation in participants measured with the TAP-score (mean of composition of intensity and duration setting administered in the TAP). We expected that athletes show higher values in the self-immersed compared to the self-distanced condition (*Hypothesis 2*). In line with Stanger et al. (2016) we performed additional exploratory analyses, and therefore split our TAP-score in a provoked and unprovoked aggression measure and identified whether there is difference between both conditions. Moreover, this study was embedded within a larger research project in which a number of students enrolled in a psychology program were already tested in a pilot study. This allowed us to create a virtual control group for an exploratory analysis of potential group differences.[1]

## MATERIALS AND METHODS

### Participants

Forty-two athletes participated in our experiment. Due to the lack of real competitive experience or misunderstanding the instructions, we excluded two athletes from our data analysis. The final subsample consisted of 40 athletes (female: 23; male: 17) from different team ($n$ = 27) and individual sports ($n$ = 13). Mean age was 23.83 years ($SD$ = 3.41). The athletes averaged 9.35 h ($SD$ = 3.71) of discipline-specific training in 3.25 training sessions ($SD$ = 1.21) and 2.36 additional sessions ($SD$ = 1.35; e.g., weight or athletic training) per week. The averaged participation in competitions per year was 14.83 ($SD$ = 11.39). Nine athletes belonged to highest to third highest national level (comparable with A- to C-squad or First German Bundesliga). Thirty-one athletes were active in the fourth highest or subjacent level (comparable with D-squat, Second German Bundesliga or below as well as participation in German Junior or regional championships).

To describe relevant personality traits in our participants we used the German versions of *Anger-Related Reactions and Goals Inventory* (ARGI; Kubiak et al., 2011) and *State-Trait-Anger Expression-Inventory 2* (STAXI-2; Rohrmann et al., 2013). Note, participants rated on a four-point scale from 1 (*almost never*) to 4 (*almost always*) only the anger-related reactions subscales from ARGI (seven subscales with four items each; Cronbach's alpha ($\alpha$) for the subscales lies between $\alpha$ = 0.74 and $\alpha$ = 0.90 for the original sample). Furthermore, we used the four trait subscales of the STAXI-2: trait anger (10 items; $\alpha$ = 0.89), anger expression out (eight items; $\alpha$ = 0.86), anger expression in (eight Items; $\alpha$ = 0.83) and anger control (10 items; $\alpha$ = 0.89). Participants rated on a four-point scale (1 = almost never, 2 = sometimes, 3 = often, 4 = almost always) how often each item described their general state of mind. **Table 1** (left side) presents an overview of the sample description as well as Cronbach's $\alpha$ for all trait measures.

### Procedure

The study protocol was approved by the local Ethics Committee of Johannes Gutenberg-University Mainz and was conducted

[1]The data, which provides the basis for the group comparisons, was collected by other responsible scientists of our research group and at a different time; moreover, the number of tested participants was higher during the first data acquisition phase ($N$ = 94). Even though the protocol and the experimental settings were the same, it should be kept in mind that the two data sets used for the group comparison were not acquired in the same project phase. We labeled the data set derived from the first data collection phase *virtual control group* to make this characteristic transparent to the reader.

**TABLE 1** | Biographical data, anger-related personality traits, and internal consistency of the applied variables separated by athletes and virtual control group.

| ***Biographical data*** | **Athletes (*n* = 40)** | | | **Control group (*n* = 40)** | | |
|---|---|---|---|---|---|---|
| ***Sex*** | ***f* = 23** | ***m* = 17** | | ***f* = 28** | ***m* = 12** | |
| ***Age*** | ***M* = 23.83** | **range = 18–31** | | ***M* = 24.05** | **range = 19–46** | |
| **Anger-related personality traits** | ***M* (*SD*)** | **95% CI** | ***α*** | ***M* (*SD*)** | **95% CI** | ***α*** |
| *Functional anger-related reactions* | | | | | | |
| Feedback | 11.05 (2.93) | [10.11, 11.99] | 0.90 | 11.51(1.93)[1] | [10.89, 12.14] | 0.68 |
| Distraction | 7.95 (2.14) | [7.27, 8.63] | 0.60 | 7.77 (2.69)[1] | [6.90, 8.64] | 0.85 |
| Downplaying | 10.58 (2.78) | [9.69, 11.46] | 0.81 | 9.73 (2.59) | [8.90, 10.55] | 0.71 |
| Humor | 6.70 (2.42) | [5.93, 7.47] | 0.80 | 5.95 (1.89) | [5.34, 6.56] | 0.75 |
| *Dysfunctional anger-related reactions* | | | | | | |
| Venting | 6.50 (1.78) | [5.93, 7.07] | 0.64 | 7.05 (2.35) | [6.30, 7.80] | 0.82 |
| Rumination | 10.75 (2.92) | [9.81, 11.69] | 0.87 | 10.28 (2.83) | [9.37, 11.18] | 0.86 |
| Submission | 8.58 (2.91) | [7.65, 9.50] | 0.79 | 7.80 (2.69) | [6.94, 8.66] | 0.78 |
| *STAXI-II* | | | | | | |
| Trait anger | 19.03 (3.92) | [17.77, 20.28] | 0.79 | 20.20 (4.38) | [18.80, 21.60] | 0.81 |
| Anger expression out | 10.72 (2.54) | [9.98, 11.54] | 0.66 | 11.10 (2.42) | [10.33, 11.87] | 0.67 |
| Anger expression in | 19.03 (7.44) | [16.65, 21.40] | 0.53 | 16.75 (4.82) | [15.21, 18.29] | 0.87 |
| Anger control | 30.03 (5.74) | [28.19, 31.86] | 0.88 | 29.79 (4.95)[1] | [28.19, 31.40] | 0.84 |

*M, mean; SD, standard deviation; 95% CI, 95% confidence intervals; α, Cronbach's alpha.* [1]*N = 39, due to technical problems, data are missing from one participant.*

according to the guidelines of the Declaration of Helsinki. Participation in this study was voluntary; athletes had the opportunity to win vouchers with a total value of 90€. Participants arrived individually at the laboratory and received information about the aims and contents of the study. All participants gave consent before completing the STAXI-2 (Rohrmann et al., 2013), the ARGI (Kubiak et al., 2011) as well as the PANAS (Krohne et al., 1996). In addition to these, the participants filled out biographical and sports-related questions as well as other questionnaires, which were unrelated to the present study. We describe the utilized questionnaires below. We also prepared a cover story to lead the participants to believe that they were competing against an actual person, and not, as in fact against a pre-programmed opponent (for more details see Manipulation of context). Participants got a short overview of the general procedure, and were informed that very loud, yet not harmful, sounds could occur during the task. Participants were also informed that they could withdraw from the experiment at any time without negative consequences; however, no participant decided to abort the experiment prematurely.

For the computer-based part of the experiment, participants were prompted to follow the instructions on the screen. Participants went through eight practice trials to get to know the task and were introduced to their opponent *via* webcam (i.e., a prerecorded video) to enhance the credibility of the existence of the opponent. Throughout the TAP, the participants were able to see their opponents after each trial expressing their reactions to the outcome. They were led to believe that the opponent could see them also *via* webcam during the defined time-window (but no recording took place during the experiment). From here on, the first experimental condition started automatically. Due to our repeated measures design, the order of conditions was randomized and counterbalanced across participants (i.e., half of the participants started with the self-immersed condition and continued with the self-distanced condition, while the others started with the self-distanced condition and continued with the self-immersed condition) for assessing affective and behavioral outcomes of self-distancing in comparison to self-immersion. The procedure of the two conditions was identical: Each condition began with the induction of the respective perspective (Kross et al., 2014), followed by a detailed description and introduction for the linguistic shift (self-immersed vs. self-distanced perspective; which they should apply for the following trials) as well as a detailed practice time. This practice time included two writing exercises (see Perspective induction). Then participants started with the TAP and played 30 trials. A 5-min break in which the participants chose between one of four neutral videos followed before they started with the second condition (consisting also of 30 trials). The structure of the second condition was identical to the first one and differed only in the new perspective that needed to be practiced with the mentioned validated procedure. After the second condition was finished, a follow-up survey were carried out. Finally, participants were debriefed (i.e., informed about the non-existence of the opponent), and asked to complete a second form in order to renew their consent after receiving full information about the aims and the procedure of the study. **Figure 1A** illustrates an overview of our study procedure.

## Perspective Induction

We used a validated procedure to induce a self-distanced (vs. self-immersed) perspective where participants engage in a short writing task using first-person or non-first-person language (Kross et al., 2014). This task required a minimum of 300 characters, and participants were asked to write about (1) their current situation and (2) a past upsetting situation in which they were angry with another person (see Kross et al., 2005). Depending on the condition, they were demanded to frame their text from either the first- or third-person perspective. To give an example, participants were asked to use their own name and the pronouns "he" or "she" in the self-distancing condition (e.g., thoughts of the participant Petra: "Petra takes part in a study and competes against an opponent. In the process, Petra gets very angry.") and the pronouns "I" and "my" in the self-immersed condition (e.g., "I take part in a study and compete against an opponent. I get very angry.") to refer to themselves as they reflect on their emotions. In addition, to check the perspective implementation during the TAP, participants were asked after each trial to which extent they were able to adopt each perspective (more details see below).

### Manipulation of Context

We took a series of steps to convince participants that they were competing against a real opponent. The experimenter left the test room twice: (a) at the beginning of the questionnaire part to confirm that the opponent had arrived, was sitting elsewhere with a second experimenter and had just started with the questionnaires and (b) before the start of the computer-based part of the study to ensure that the opponent was also almost ready to start. The participant was told that that he or she could start with the task and that small delays could appear during the task due to synchronization with the opponent (we implemented short waiting periods between the individual parts of the task to increase credibility). We also used a webcam and performed a technical check to ensure that the camera was working and the participants were correctly positioned in front of the webcam. Finally, we added short videos of the opponent's reaction (same sex as participant) to the outcome feedback of the task, which is not typical for the TAP procedure, to increase credibility on the one hand and provocation on the other hand.

In addition, we asked the participants at the end of the study to evaluate the credibility of the experimental setting. For this purpose, we used a five-point Likert-scale from 1 (*not credible at all*) to 5 (*very credible*). On average the participants reported a credibility of 3.18 ($SD$ = 1.02). **Figure 2** illustrates the distribution of the participants' individual rating values.

## Measures

### The Taylor Aggression Paradigm

The TAP (Taylor, 1967) is a laboratory measure of interpersonal aggression. In its most common version, participants administer noise blasts to an opponent, who ostensibly does the same for them. In brief, participants repeatedly compete against this

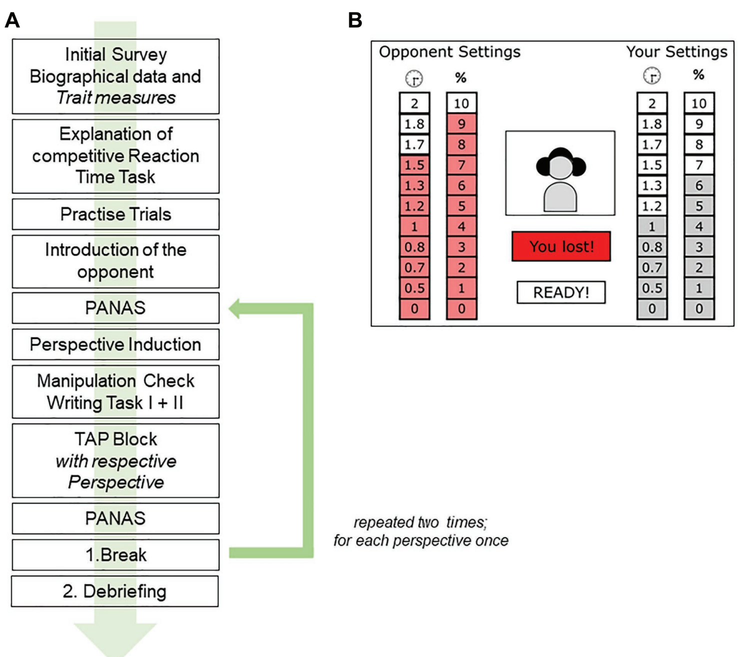


**FIGURE 1 | (A)** Overview of the procedure starting with initial survey, in which the trait measures were collected, followed by detailed explanation of the competitive Reaction Time Task and eight practice trials to get familiar with the game mode. After that participants' opponent is introduced, followed by asking the momentary affective state, leading to induction of the respective perspective and the corresponding writing tasks (as part of our manipulation check) before the Taylor Aggression Paradigm (TAP) starts. After the TAP, momentary affective state [post measure of the Positive and Negative Affect Schedule (PANAS)] is queried before the break starts. After that, the second condition with the other perspective starts. **(B)** The participant uses the depicted display to set his/her responses to perform the response task, and to receive the feedback. The example shows a typical display of a TAP-trial, where the participant lost. On the left side are the duration and intensity settings of the (virtual) opponent, and on the right side are the participants' settings, which were chosen before each trial.

virtual opponent with the aim of reacting as quickly as possible when a target on the screen turns red. If they lose the competition, participants receive a noise blast that their supposed opponent chose. Participants can see the duration and the intensity of the noise blast that their opponent selects for them, which is intended to intensify experiences of anger. If they win the competition, the opponent receives the noise blast that the participants chose (i.e., intensity volume between 60–105 decibels, in 5-decibel increments and duration: 0–2 s, in 0.5-s increments; see **Figure 1B** for the representation of the setting). The settings of the participant represent the operationalization of aggressive behavior. For the purpose of our study, we used a well-established TAP variant, with a trial structure based on pre-registered findings by Chester and Lasko (2018; i.e., the Reaction Time Measure of Aggression, version 2.9.9.9 by Bushman and Baumeister, 1998). In case of losing a trial (50% probability with randomized order of wins and losses; random order was held constant across participants), participants were presented a noise blast of the intensity and duration ostensibly set by their opponent (preprogrammed to set only upper scale intensity and duration levels).

### Evaluation of Perspective Taking

We measured successful perspective implementation stepwise. First, participants rated on a seven-point Likert scale from 1 (*not at all*) to 7 (*exclusively*) to which extent they were able to adopt each perspective after each trial. In addition, we counted the use of first- and third-person pronouns in the writing task across conditions and compared the average use.

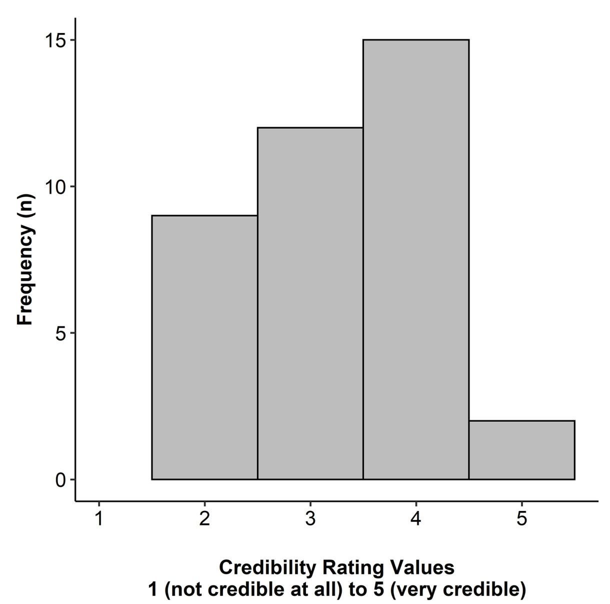


**FIGURE 2** | Distribution of the participants' individual credibility rating ($N$ = 38). Due to technical problems, rating data of two participants is missing.

### Positive and Negative Affect

The PANAS (Krohne et al., 1996; English original version: Watson et al., 1988) was used to measure affective state. The PANAS includes 20 items to assess both positive and negative state affectivity (PA and NA), each with 10 items. Participants were asked to rate the degree to which they feel the emotional state described in each item, on a five-point Likert Scale, ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). Cronbach's $\alpha$ = 0.85 (PA) and $\alpha$ = 0.86 (NA).

### Anger

As described by Watson et al. (1988), the PANAS also allows to derive a measure of anger. Following the suggestions of Kross et al. (2005), we computed an anger index (Discrete Anger Index in the terminology of Kross et al., 2005) defined as the average of the two anger-related PANAS items ("hostile" and "irritable"; see Watson et al., 1988). The test score of the anger index ranges from 1 to 5.

### Aggression

In line with Chester and Lasko (2018), intensity and duration values were aggregated to a mean composite TAP-score as measure for aggression. In addition, we analyzed two further approaches, analogous with Stanger et al. (2016), to measure aggression: the first one is unprovoked or proactive aggression, which specified the extent of TAP-score chosen by the participant on the first trial in each condition, before receiving any noise blasts. Provoked or reactive aggression is the second measure and is operationalized as the extent of TAP-scores chosen on subsequent trials.

## Data Analysis

The data collection of experimental data was carried out with Inquisit (Version 4, Millisecond Software, Seattle, WA), and data preparation and all statistical analyses were performed with the software RStudio (RStudio Team, 2016).

### Statistical Tests

With regard to our manipulation check (including subjective ratings as well as the use of first-person pronouns and third-person pronouns), we analyzed mean differences between conditions with paired $t$-tests. Beforehand, we checked the requirements for the application (normal distribution and homogeneity of variances). We conducted a Shapiro Wilk Test for testing the assumption of normality ($p$ > 0.05) and a Levene's Test for testing the homogeneity of variance ($p$ > 0.05). In case of non-parametric distribution, we reported the significance of Wilcox signed-rank test as robust alternative for a dependent $t$-test ($p_{wilcox}$; Field et al., 2012). To analyze the effects of positive affect, negative effect, and anger we applied 2x2 repeated measure analyses of variance (rmANOVAs) using the ezANOVA-function ("*ez*" R-package; Lawrence, 2016) to include measurement time as a factor. Regarding the behavioral response, we applied the following analyses: First, to test for the general effect of the different perspectives, we performed a paired $t$-tests to investigate overall aggression based on the TAP-scores of all trials of our TAP-paradigm. In essence, this is the main test regarding Hypothesis 2. However, to further analyze the effect of self-distancing on the behavioral responses, we added a second analysis: According to Stanger et al. (2016) we performed an additional 2x2 ANOVA with a condition factor (self-immersed vs. self-distanced) and a type of aggression factor (unprovoked vs. provoked) as well as the TAP-score as dependent variable. Thereby, unprovoked aggression corresponded to the TAP-score of the first trial in each condition and provoked aggression corresponded to the extent of TAP-scores chosen on the subsequent trials. Third, based on the idea, that besides provoked and unprovoked aggression, wins and losses also reflect different types of aggression (Giancola and Parrott, 2008; Chester and Lasko, 2018), we carried out another variance analysis. Therefore, we took the outcome of each trial (wins vs. losses) into account and performed a 2x2 ANOVA with the overall TAP-score as dependent variable and outcome (wins vs. losses) as well as condition (self-immersed vs. self-distanced) as independent variables.

### Effect Sizes

We reported the effect size of mean differences between conditions with Cohen's $d$ (Cohen, 1988) with the following criteria: $d = 0.10$, $d = 0.25$, and $d = 0.50$ for small, medium, and large effects. In case of non-parametric distribution, we reported the significance of Wilcox signed-rank test as robust alternative for a dependent $t$-test ($p_{wilcox}$; Field et al., 2012) with corresponding robust effect size ($r$). The interpretation values for $r$ are: 0.10 to <0.30 for a small effect, 0.30 to <0.50 for a moderate effect and ≥0.5 for a large effect (Cohen, 1992). For the ANOVAs we reported partial eta squared ($\eta_p^2$) as a measure of effect with the following criteria for small, medium, and large effect: 0.01, 0.06, and > 0.14 (Cohen, 1968; Vacha-Haase and Thompson, 2004).

## RESULTS

**Table 2** presents descriptive statistics (mean, standard deviation, and respective 95% confidence intervals) for perspective taking, positive and negative affect, anger, and aggression separated by condition.

### Perspective Taking

With regard to our manipulation check, results of the subjective ratings showed no significant difference between the self-distanced and the self-immersed condition [$M_\Delta = 0.08$, 95%CI (−0.35, 0.52), $t(39) = 0.39$, $p = 0.702$, $d = 0.06$]. Furthermore, participants used significantly more first-person pronouns in the self-immersed condition than in the self-distanced condition ($p_{wilcox} < 0.001$, $r = -0.62$). The same applied for the use of third-person pronouns: Participants used significantly more third-person pronouns in the self-distanced condition compared to the self-immersed condition ($p_{wilcox} < 0.001$, $r = -0.55$).

### Positive and Negative Affect

For the Positive Affect Scale neither a significant main effect of condition [$F(1,39) = 0.71$, $p = 0.405$, $\eta_p^2 = 0.02$] nor for measurement time [$F(1,39) = 0.06$, $p = 0.804$, $\eta_p^2 < 0.01$] appeared. Moreover, an interaction effect [$F(1,39) = 2.19$, $p = 0.147$, $\eta_p^2 = 0.05$] did not reach significance. **Figure 3A** depicts the mean scores for positive affect.

Instead, for negative affect, there was a significant main effect of measurement time [$F(1,39) = 4.96$, $p = 0.032$, $\eta_p^2 = 0.11$] but not for condition [$F(1,39) = 1.48$, $p = 0.231$, $\eta_p^2 = 0.04$]. In addition, the condition × measurement time interaction was significant [$F(1,39) = 6.77$, $p = 0.013$, $\eta_p^2 = 0.15$]. Bonferroni *post hoc* tests revealed that for the self-immersed condition there was a significant difference between negative affect before and after the TAP ($p_{bonf} = 0.021$); for the self-distanced condition, no difference between before and after the TAP ($p_{bonf} = 0.999$) appeared. There was also a tendency for a difference of negative affect after the TAP between both conditions ($p_{bonf} < 0.069$). **Figure 3B** illustrates the mean scores negative affect.

**TABLE 2** | Selected variables regarding application of perspectives, affect, anger, and aggression measures of the athletes separated by the respective perspective.

| | Athletes (*n* = 40) | | | |
|---|---|---|---|---|
| | Self-immersed | | Self-distanced | |
| | *M* (*SD*) | 95% CI | *M* (*SD*) | 95% CI |
| *Perspective taking* | | | | |
| Perspective rating | 4.68 (1.33) | [4.25, 5.11] | 4.76 (1.28) | [4.35, 5.17] |
| First-person pronouns | 15.55 (5.54) | [13.78, 17.32] | 0.78 (2.56) | [−0.04, 1.59] |
| Third-person pronouns | 2.55 (2.42) | [1.78, 3.32] | 9.19 (5.43) | [7.36, 10.84] |
| *Affect and Anger* | | | | |
| Positive affect pre | 28.73 (8.30) | [26.07, 31.38] | 28.83 (8.43) | [26.13, 31.52] |
| Positive affect post | 29.95 (8.43) | [27.25, 32.64] | 27.93 (8.48) | [25.21, 30.64] |
| Negative affect pre | 12.30 (2.28) | [11.57, 13.03] | 12.58 (2.65) | [11.73, 13.42] |
| Negative affect post | 13.88 (3.75) | [12.68, 15.07] | 12.58 (2.67) | [11.72, 13.43] |
| Anger pre | 1.16 (0.40) | [1.04, 1.29] | 1.11 (0.29) | [1.02, 1.20] |
| Anger post | 1.46 (0.57) | [1.28, 1.64] | 1.29 (0.53) | [1.12, 1.46] |
| *Aggression* | | | | |
| TAP | 5.22 (1.55) | [4.72, 5.71] | 4.66 (1.81) | [4.08, 5.24] |
| Unprovoked aggression | 4.48 (2.14) | [3.79, 5.16] | 3.41 (1.73) | [2.86, 3.97] |
| Provoked aggression | 5.24 (1.56) | [4.74, 5.74] | 4.71 (1.84) | [4.12, 5.29] |
| *Outcome of the task* | | | | |
| Wins | 5.25 (2.43) | [5.06, 5.44] | 4.59 (2.36) | [4.41, 4.78] |
| Losses | 5.18 (2.41) | [4.99, 5.38] | 4.74 (2.31) | [4.55, 4.92] |

*M, mean; SD, standard deviation; 95% CI, 95% confidence intervals.*

### Anger

Results for the anger index indicated two main effects for condition [$F(1,39) = 4.65$, $p = 0.037$, $\eta_p^2 = 0.11$] and measurement time [$F(1,39) = 19.58$, $p < 0.001$, $\eta_p^2 = 0.33$], but there was no significant condition x measurement time interaction [$F(1,39) = 1.14$, $p = 0.292$, $\eta_p^2 = 0.03$; see **Figure 3C**].

### Aggression

Results of the paired $t$-test indicated significant differences for overall aggression between the self-distanced and the self-immersed condition [$M_\Delta = -0.55$, 95%CI (−0.99, −0.12), $t(39) = -2.58$, $p = 0.014$, $d = 0.33$, see **Figure 4A**]. Moreover, results of the

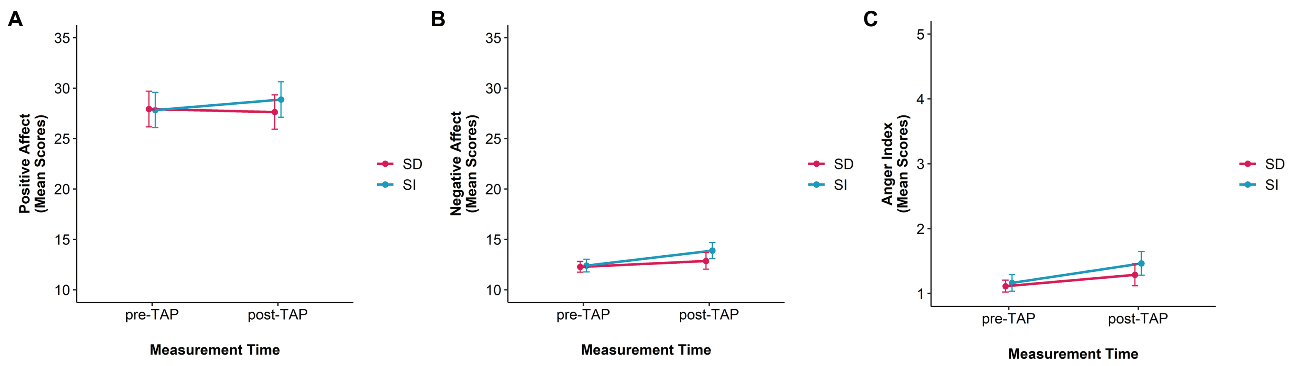


**FIGURE 3 |** Mean PANAS-Scores separated by **(A)** positive and **(B)** negative affect, and **(C)** mean anger scores [mean values of summarized Positive and Negative Affect Schedule (PANAS) items "hostile" and "irritable"] are presented before and after the Taylor Aggression Paradigm (TAP), separated by condition [self-distanced (SD) vs. self-immersed (SI)]. Note: PANAS scales for positive affect and negative affect range from 10 to 50 **(A,B)** and from 1 to 5 for the anger index **(C)**.

2x2 ANOVA revealed significant effects for type of aggression [$F(1,39) = 27.74$, $p < 0.001$, $\eta_p^2 = 0.42$] and for condition [$F(1,39) = 15.55$, $p < 0.001$, $\eta_p^2 = 0.29$]. The interaction was non-significant [$F(1,39) = 2.48$, $p = 0.123$, $\eta_p^2 = 0.06$]. **Figures 4B,C** display TAP-scores for unprovoked and provoked aggression. Further, the results of the 2x2 ANOVA with the overall TAP-score as dependent variable and outcome (wins vs. losses) as well as condition (self-immersed vs. self-distanced) as independent variables showed no significant differences between wins and losses [$F(1,78) < 0.01$, $p = 0.935$, $\eta_p^2 < 0.01$]. Moreover, significant results were observed only with regard to the condition [$F(1,78) = 11.62$, $p = 0.001$, $\eta_p^2 = 0.13$]. Moreover, there was no significant interaction effect [$F(1,78) = 0.25$, $p = 0.616$, $\eta_p^2 < 0.01$].

## Exploratory Analysis of Potential Group Differences

In addition, we had the possibility to compare the athletes' data with a virtual control group composed out of a sample from a larger research project.[2] For our purposes, we performed a propensity score matching using gender, age and trait anger as matching variables. We carried out the matching procedure with the nearest neighbor method from the "*MatchIt*" R-package (Ho et al., 2011). The virtual control group consisted of 40 psychology students (female: 28; male: 12) from both undergraduate ($n = 24$) and graduate ($n = 16$) levels. The mean age was 24.05 years ($SD = 5.53$). At first, we analyzed the anger-related personality traits. **Table 1** (right side) presents the sample characteristics in comparison to the athletes. Second, we investigated the ability of perspective application, affectivity as well as the anger index and aggression measures. Analogous to the athletes' sample we tested for mean differences between conditions in different ways: regarding our manipulation check (including the subjective rating, and the use of first-person-pronouns and third-person-pronouns) we used the Wilcox signed-rank test for paired *t*-tests. Moreover, we performed 2x2 rmANOVAs to take the measurement time of negative affect and anger into account. With regard to aggression, we applied a Wilcox signed-rank test for paired *t*-tests for overall aggression and a 2x2 ANOVA with type of aggression (unprovoked vs. provoked) and condition (self-immersed vs. self-distanced) to investigate detailed differences regarding the TAP-scores. Third, we applied a 2x2 ANOVA with group (athletes vs. virtual control group) as a between-subject factor and condition (self-immersed vs. self-distanced) as within-subject factor and tested for group differences in the variables related to our manipulation check. Fourth, we computed two three-way rmANOVAs to determine whether there were significant interactions between group (athletes vs. virtual control group), condition (self-immersed vs. self-distanced) and measurement time (pre-TAP vs. post-TAP) of negative affect and anger. Fifth and last, we applied a 2x2 ANOVA with a group factor (athletes vs. virtual control group) and a condition factor (self-immersed vs. self-distanced) to investigate differences in overall aggression. With regard to unprovoked and provoked aggression, we performed a mixed effect three-way ANOVA with the TAP-score as dependent variable and condition (self-immersed vs. self-distanced), type of aggression (unprovoked vs. provoked), and group (athletes vs. virtual control group) as independent variables.

**Table 3** depicts a sample overview of means, standard deviations and 95% confidence intervals of the virtual control group for both conditions and allows for comparison with the athletes' data.

### Perspective Taking

The virtual control group showed no differences in the perspective rating ($p_{wilcox} = 0.050$, $r = 0.22$), and significant differences in the use of first-person-pronouns ($p_{wilcox} < 0.001$, $r = 0.62$) and third-person pronouns ($p_{wilcox} < 0.001$, $r = 0.60$) between the self-immersed and the self-distanced condition.

### Negative Affect and Anger

Results of the 2x2 rmANOVA for negative affect and anger indicated for both variables a significant measurement time effect [negative affect: $F(1,78) = 4.33$, $p = 0.041$, $\eta_p^2 = 0.05$;

[2]See OSF: https://osf.io/h5wuj/?view_only=41051d01ebca4b2a97a36e013dc8c146

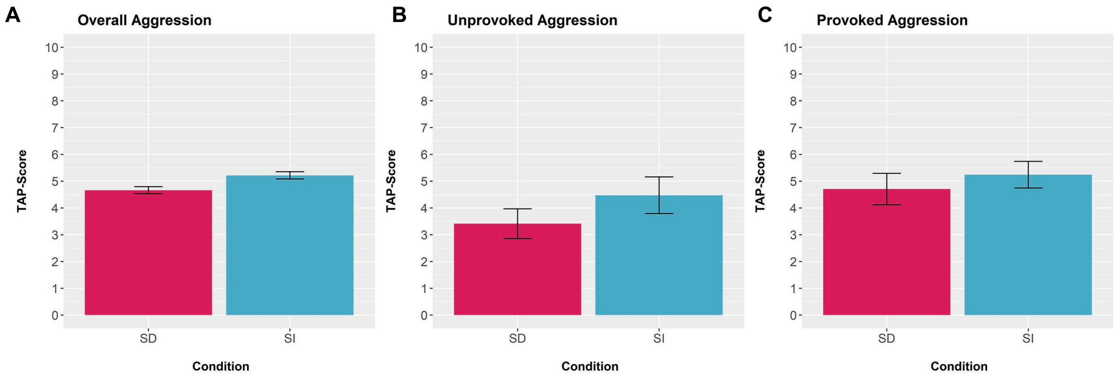


**FIGURE 4 |** Summary of the TAP-scores in the self-distanced (SD) and self-immersed (SI) condition. Differences between SD and SI perspective are visible for **(A)** overall aggression, **(B)** unprovoked aggression, and **(C)** provoked aggression. All aggression scores displayed the mean levels of aggregated intensity and duration values with a range from 0 to 10. Error bars represent 95% confidence intervals.

**TABLE 3 |** Selected variables regarding application of perspectives, affect, anger, and aggression measures of the virtual control group separated by the respective perspective.

| | **Control group (*n* = 40)** | | | |
|---|---|---|---|---|
| | **Self-immersed** | | **Self-distanced** | |
| | ***M* (*SD*)** | **95% CI** | ***M* (*SD*)** | **95% CI** |
| *Perspective taking* | | | | |
| Perspective rating | 4.62 (1.64) | [4.09, 5.15] | 4.42 (1.52) | [3.93, 4.90] |
| First-person pronouns | 16.50 (5.44) | [14.76, 18.24] | 0.33 (1.14) | [−0.04, 0.69] |
| Third-person pronouns | 2.63 (1.81) | [2.05, 3.20] | 9.95 (4.08) | [8.64, 11.25] |
| *Affect and Anger* | | | | |
| Negative affect pre | 12.05 (2.80) | [11.15, 12.95] | 12.23 (3.17) | [11.21, 13.24] |
| Negative affect post | 13.30 (3.70) | [12.12, 14.48] | 12.63 (4.37) | [11.23, 14.02] |
| Anger pre | 1.08 (0.24) | [1.00, 1.15] | 1.10 (0.26) | [1.02, 1.18] |
| Anger post | 1.54 (0.73) | [1.30, 1.77] | 1.31 (0.61) | [1.12, 1.51] |
| *Aggression* | | | | |
| TAP | 3.38 (2.46) | [2.59, 4.17] | 2.81 (2.53) | [2.00, 3.62] |
| Unprovoked aggression | 2.50 (2.51) | [1.70, 3.30] | 2.41 (2.61) | [1.58, 2.25] |
| Provoked aggression | 3.41 (2.48) | [2.62, 4.20] | 2.82 (2.55) | [2.01, 3.64] |

*M, mean; SD, standard deviation; 95% CI, 95% confidence intervals.*

anger: $F(1,78) = 22.46$, $p < 0.001$, $\eta_p^2 = 0.22$, see **Figures 5A,B**]. Condition effects between self-distanced and self-immersed condition neither appeared for negative affect [$F(1,78) = 0.13$, $p = 0.718$, $\eta_p^2 < 0.01$) nor for anger ($F(1,78) = 1.29$, $p = 0.259$, $\eta_p^2 = 0.02$]. The same applied to the condition × measurement time interaction for negative affect [$F(1,78) = 1.15$, $p = 0.287$, $\eta_p^2 = 0.01$] and anger [$F(1,78) = 3.08$, $p = 0.083$, $\eta_p^2 = 0.04$].

### Aggression

Regarding the different types of aggression, the virtual control group differed in the overall TAP-score between the self-immersed and the self-distanced condition ($p_{wilcox} < 0.01$, $r = 0.32$). Furthermore, results of the 2x2 ANOVA revealed significant effects for the type of aggression [$F(1,39) = 10.25$, $p = 0.002$, $\eta_p^2 = 0.21$] and for the condition [$F(1,39) = 4.82$, $p = 0.034$, $\eta_p^2 = 0.11$]. The interaction was non-significant [$F(1,39) = 2.73$, $p = 0.107$, $\eta_p^2 = 0.07$].

## Group Differences Between Athletes and Virtual Control Group

### Perspective Taking

With regard to the group differences between athletes and the virtual control group, results of the 2x2 ANOVA revealed neither a significant group effect for perspective ratings [$F(1,78) = 0.56$, $p = 0.458$, $\eta_p^2 < 0.01$] nor for the use of first-person pronouns [$F(1,78) = 0.13$, $p = 0.715$, $\eta_p^2 < 0.01$] or third-person pronouns [$F(1,78) = 0.67$, $p = 0.413$, $\eta_p^2 < 0.01$]. However, significant condition effects for both linguistic uses remained [first-person pronouns: $F(1,78) = 617.30$, $p < 0.001$, $\eta_p^2 = 0.89$; third-person pronouns: $F(1,78) = 129.75$, $p < 0.001$, $\eta_p^2 = 0.62$], but not for perspective rating [$F(1,78) = 0.11$, $p = 0.737$, $\eta_p^2 < 0.01$]. Interaction effects of these three perspective variables were not significant [$F$'s < 1 for perspective rating and use of third-person pronouns, and $F(1,78) = 1.26$ for use of first-person pronouns].

### Negative Affect and Anger

For negative affect, no significant three-way interaction was obtained [$F(1,78) = 0.59$, $p = 0.446$, $\eta_p^2 < 0.01$] but the factor measurement time [$F(1,78) = 8.46$, $p = 0.004$, $\eta_p^2 = 0.10$] and the two-way interaction of measurement time x condition [$F(1,78) = 6.57$, $p = 0.012$, $\eta_p^2 = 0.08$] revealed significant effects. No further significant effects were obtained [with $F(1,78) = 1.62$ for group factor and all other $F$'s < 1]. For anger, the three-way rmANOVA revealed also a non-significant three-way interaction [$F(1,78) = 0.67$, $p = 0.415$, $\eta_p^2 < 0.01$], but significant effects of measurement time [$F(1,78) = 31.14$, $p < 0.001$, $\eta_p^2 = 0.29$], condition [$F(1,78) = 8.08$, $p = 0.006$, $\eta_p^2 = 0.09$] and the two-way interaction of measurement time and condition [$F(1,78) = 6.03$, $p = 0.016$, $\eta_p^2 = 0.07$]. All other effects of anger were non-significant ($F$'s < 1).

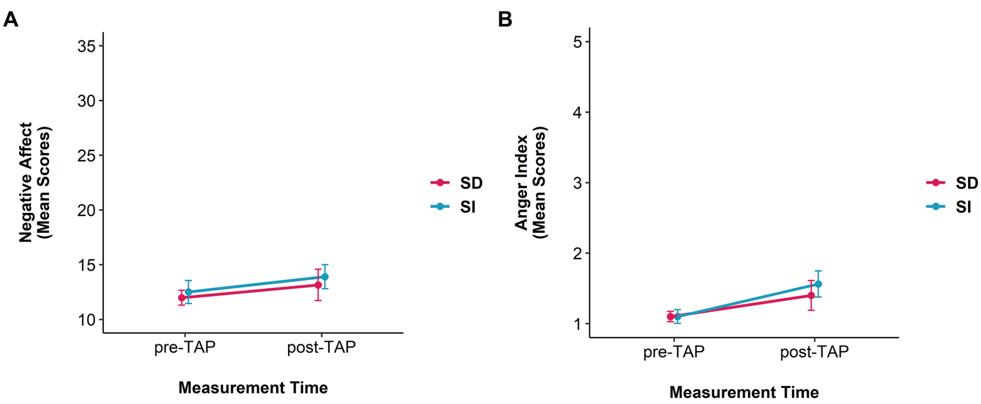


**FIGURE 5 | (A)** Mean negative affect scores (cutout of the NA scale full range score, which is from 10 to 50), and **(B)** mean values of the summarized positive and negative affect schedule (PANAS) items "hostile" and "irritable" for virtual control group before and after the taylor aggression paradigm (TAP) seperated by condition [(SD) self-distanced vs. (SI) self-immersed].

## Aggression

Interestingly, significant group differences appeared with regard to the overall aggression [$F(1,78) = 16.54$, $p < 0.001$, $\eta_p^2 = 0.17$]. Furthermore, the mixed effect three-way ANOVA revealed significant effects for the three-way interaction [$F(1,78) = 5.17$, $p = 0.026$, $\eta_p^2 = 0.06$], the group [$F(1,78) = 14.32$, $p < 0.001$, $\eta_p^2 = 0.16$], the condition [$F(1,78) = 19.97$, $p < 0.001$, $\eta_p^2 = 0.20$], and the type of aggression [$F(1,78) = 35.38$, $p < 0.001$, $\eta_p^2 = 0.31$]. In more detail, Bonferroni *post hoc* analyses showed significant differences between groups regarding unprovoked aggression ($p_{bonf} = 0.039$) and provoked aggression ($p_{bonf} = 0.009$) in the self-immersed condition. Regarding the self-distanced condition, neither a significant difference of unprovoked aggression ($p_{bonf} = 0.999$), nor of provoked aggression ($p_{bonf} = 0.058$) between athletes and the virtual control group appeared.

# DISCUSSION

The present study aimed at investigating the efficacy of self-distancing as an emotion-regulation tool for competitive athletes in a controlled laboratory setting. More specifically, we tested whether participants were equally able to adopt a self-distanced perspective as well as a self-immersed perspective, and whether their altered perspective modulated the subjective experience and behavioral response in the context of interpersonal provocation. First, athletes were able to adopt a self-distanced and a self-immersed perspective by following the respective instructions (which were randomly assigned to either the first or the second block of the experiment). Therefore, our results reveal successful and flexible application of a self-distancing perspective in athletes. In addition, our results support the idea that a self-distanced perspective can be a useful tool for regulating negative affect and aggressive behavior after interpersonal provocation. This result is partly mirrored in the reported values of anger, which were lower in the self-distanced condition compared to the self-immersed condition.

In detail, our manipulation check showed that participants were equally able to adopt either a self-distanced or a self-immersed perspective, which was depicted by subjective ratings of perspective taking ("1" *not at all* to "7" *exclusively*). This is supported by the observable use of first- and third-person pronouns in the respective perspective. In the self-immersed condition, participants almost exclusively used first-person self-talk, whereas in the self-distanced condition they predominately used third-person self-talk. This is in line with previous findings and stresses the effortlessness of self-distancing as a self-regulation strategy (Kross and Ayduk, 2017). In addition, exploratory comparisons with a virtual control group demonstrate that this effect seems to generalize.

On the one hand, adapting a self-distanced perspective seems to represent an effortless process. On the other hand, this strategy has significant consequences for the subjective affective experience: We found that negative affect (i.e., negative affect scale of the PANAS) was lowered in response to provocation as induced *via* the TAP, when participants adapted a self-distanced perspective. A comparable, albeit weaker pattern emerged for the anger index (*Hypothesis 1*). More importantly, a self-distanced compared to a self-immersed perspective reduced athletes' aggressive behavior during the TAP (*Hypothesis 2*). Moreover, following the method of Stanger et al. (2016) and splitting the overall TAP-score as behavioral outcome for aggression in unprovoked (only the first trial of the TAP for each condition) and provoked aggression (all other trials of the TAP), results obtained the same pattern. However, a differentiation into win and lose trials did not provide further insight into the effects of self-distancing in our study.

The comparison of the athletes' responses with those from a virtual control group (derived from a bigger sample of students without special expertise in competitive sports) added two main insights: First, both groups were equally well able to adapt the two perspectives. Second, the overall pattern of results was comparable, further supporting the general applicability of the respective emotion-regulation strategy. Third, irrespective of the perspective, competitive athletes showed higher levels in all three aggression measures. Since the group comparison was only a *post hoc* (exploratory) analysis, far-reaching interpretations of these results are not possible. However, the results suggest that it is worth applying this approach in more systematic group comparisons, for instance, to evaluate whether competitive athletes tend to more aggressive behavior in this type of personal interaction (at least if a competitive aspect is included).

Taken together, our findings support previous research showing that perspective taking is a relevant self-regulation strategy in interpersonal provocation, because our data indicate that it reduces aggression toward an opponent, among competitive athletes (Kross et al., 2005; Stanger et al., 2016; Kross and Ayduk, 2017). In detail, the present study supports the idea that self-distancing buffers negative affect and anger. Although the differences were small, participants reported higher levels of negative affect and anger (in terms of the anger index) after the interpersonal provocation in the self-immersed condition. This effect, however, disappeared when participants applied the self-distancing technique. Nevertheless, the differences must be considered to be minimal, on the one hand. On the other hand, this is not surprising, because we performed an experimental setting in the laboratory under controlled conditions, which obviously does not comprise the complex person-environment interaction. In addition, the personal significance of the provocation was presumably lower in our laboratory setting compared to anger provoking situations in "real-life" competitive contexts. Therefore, it is even more remarkable that a small effect remains in the artificial laboratory setting, which suggests that the effect is quite reliable. In line with Kross and Ayduk (2017), who highlighted the suitability for daily use of self-talk application to help individuals to cope effectively with stressors, our results could indicate larger effects in situations with increasing relevance in daily sports practice. To summarize, two major conclusions can be drawn from these findings: (a) our modified TAP version with pre-programmed video sequences (i.e., Chester and Lasko, 2018) successfully induces subjectively experienced negative responses (as mirrored in the PANAS, the anger index, and the TAP-score). (b) Self-distancing constitutes an effective strategy to modulate the (negative) outcome of interpersonal provocation on different levels (affect, anger, and aggression).

The TAP is an established measurement for interpersonal aggression (Chester and Lasko, 2018), which includes sports-relevant elements like the competitive character and provocation (see also Stanger et al., 2016). However, it is obvious that a laboratory task cannot tap the complexity of sports practice (especially during a competition). Athletes experience different triggers for anger and aggression in sports-specific situations such as physical contact with opponents (e.g., pushing, elbowing, or kicking), due to incomprehensible decisions of a referee, or due to mocking opponents. This results in two shortcomings for the application of our experimental setting in athletes: the lack of proximity to the natural environment and the personal relevance for their performance in their own sports. For instance, higher TAP-scores among athletes in contrast to the comparison group may suggest that athletes are more willing to take a risk, setting higher noise blasts with the knowledge that this has no relevant consequences for them. An important next step will be the methodological transfer of this experimental setting to sport-specific situations to test whether it is also suitable for further competition-relevant aspects. This could be accomplished by combining the data obtained with the laboratory TAP procedure with data from field studies including, for instance, observed aggressive behavior during a match and the (potentially negative) consequences of this behavior like free throws in basketball or a penalty in soccer. The overall aim of such a research strategy would be to identify correlations of the individual athletes' ability to self-distance with performance in competitions or to identify effective emotion-regulation strategies for competitive sports in different disciplines.

One further limitation of our study is the application of the anger index. Following the recommendations of Watson et al. (1988, see also Kross et al., 2005), we computed this index from the PANAS items "hostile" and "irritable." However, these do not optimally reflect anger (with all of its facets). In future studies, direct measures of anger should be applied to obtain more detailed information. For instance, the well-established STAXI-2 (Rohrmann et al., 2013) would be suitable as a general non-sport-specific measure. With regard to sport specific anger, the Sport Emotion Questionnaire (SEQ; Jones et al., 2005) and the Brunel Mood Scale (BRUMS; Terry et al., 1999, 2003) with their respective anger subscales are a good fit. Moreover, the application of measures of unprovoked and provoked aggression in our experimental design should also be addressed. We applied the idea from Stanger et al. (2016) and also split our TAP-score in these two measures. However, two aspects must be considered: Firstly, we used another version of the TAP to measure aggression as behavioral outcome. Stanger et al. (2016) used the version in which electro shocks were administered to the opponent (Giancola and Parrott, 2008), whereas we used noise blasts (Chester and Lasko, 2018, i.e., version 2.9.9.9 by Bushman and Baumeister, 1998). Secondly, we measured unprovoked aggression as first trial after induction of each perspective and not as absolute first trial of the whole paradigm. Therefore, the results must be interpreted with caution, as experience with the paradigm increases.

Nevertheless, we believe that the TAP may also be applied as tool for practicing effective self-regulation. Here, the controlled laboratory setting would have three advantages: First, it can be repeated at will without the athletes having to go through the physical strain associated with competition or competition-like training. At the same time, the mental stress is reduced for the time being (e.g., there is no social pressure because the athlete could practice alone). Thus, this form of training does not increase the overall strain on athletes. Second, in principal it is possible to combine the task with feedback for the athlete to demonstrate the efficacy of the self-regulation during the practice. For instance, the athlete could be asked to rate the initial and the final arousal or stress level by means of a visual analog scale and could be presented with the difference under the self-immersed and the self-distanced instruction. Third, because the corresponding strategies are easy to learn and implement (which will also be mirrored in the feedback), such training also increases confidence in one's own competence and thus lowers the threshold to apply the method in the field. However, these considerations are still very speculative at this point; more research is needed to test and exploit the potential of such an intervention.

## CONCLUSION

Self-distancing is an effective emotion regulation strategy. Our study illustrates that it works equally well in athletes. The advantage of using self-distancing as a strategy in situations of interpersonal provocation are that it is a relatively effortless self-control process and that it can be applied flexibly to situational demands. Self-distancing can help athletes to downregulate angry feelings and buffer aggressive reactions by social provocation in competitive context. Therefore, self-distancing seems to be a promising tool for athletes to stay action-oriented and reach optimal performance in critical situations in daily sports practice and competitions.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of Johannes Gutenberg-University Mainz. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

AK, AM-K, and SB conceptualized the experimental setting. LH generated video-sequences and collected data of psychology students with AK. AM-K collected data of athletes and performed the statistical analyses. AM-K and SB wrote the manuscript. All authors contributed to the article and approved the submitted version.

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# *Bifidobacterium animalis* subsp. *lactis* BB-12 Improves the State Anxiety and Sports Performance of Young Divers Under Stress Situations: A Single-Arm, Prospective Proof-of-Concept Study

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**Background:** Athletes will increase their state anxiety under stress situations, which will lead to the decline of sports performance. The improvement of anxiety by probiotics has been reported, but there is a lack of research in the athlete population. The purpose of the current study is to explore the effectiveness of probiotics in improving athletes' state anxiety and sports performance under stress situations.

**Methods:** We conducted this single-arm study in Chongqing Institute of Sports Technology. In the 8-week study, 21 Chongqing young divers (mean age: 9.10 ± 1.80) were given probiotic *Bifidobacterium animalis* subsp. *lactis BB-12* ($1 \times 10^9$ colony-forming units/100 g) daily. The state anxiety and sports performance of athletes were measured before, during, and after the intervention, and the gut microbiota of athletes was measured before and after the intervention.

**Results:** The intervention results showed that cognitive state anxiety, somatic state anxiety, and anxiety emotion were improved (cognitive: $Z = -3.964$, $P < 0.001$; somatic: $Z = -3.079$, $P = 0.003$; anxiety: $Z = -2.973$, $P < 0.001$). In terms of gut microbiota, the intervention did not change the gut microbial composition (such as α diversity and β diversity) but increased the abundance of *Bifidobacteriaceae*. At the 8th week, the performance of athletes under stress was significantly improved ($\chi^2 = 7.88$, $P = 0.019$).

**Limitations:** First of all, due to the restriction of the number of subjects in this study, there was no control group. Secondly, although the athletes' diet was recorded in this study, the influence of this factor on gut microbiota was not eliminated. Finally, the anxiety level of the athletes in this study was obtained through a self-report, lacking physiological data in state anxiety.

**Conclusion:** The results show that probiotics intervention can improve the state anxiety of athletes under stress situation and improve the performance of athletes under stress situation.

**Keywords: probiotics, state anxiety, gut microbiota, sports performance, diver**

## INTRODUCTION

The intake of probiotics has some beneficial effects on individuals. In addition to the potential applications of probiotics in anti-tumor, anti-diabetic, anti-obesity, anti-inflammatory, anti-cancer, antiallergic, and angiogenic activities and other aspects mentioned in previous studies, it was also found that probiotics may affect the brain and the central nervous system (CNS) (George Kerry et al., 2018). The "microbiota–gut–brain axis" is an interactive, bidirectional communication established by the exchange of regulatory signals between the gastrointestinal tract and CNS (Mayer et al., 2015). Early human studies suggest that altering the microbiota with beneficial bacteria, or probiotics, can lead to changes in brain function as well as subjective reports of mood (Tillisch, 2014; Mayer et al., 2015). Considering the applicability of probiotics, several studies have focused on the benefits of probiotics for athletes. Probiotics have been shown to play a role in improving the athletes' immune xsystem, oxidative stress, metabolism, and cognitive ability (Jäger et al., 2019). After the intake of *Bifidobacteria*, the maximum oxygen uptake of swimmers was increased (Salarkia et al., 2013), and the intake of *Bifidobacteria* in marathon athletes could reduce their gastrointestinal symptoms and plasma endotoxin levels after the competition (Roberts et al., 2016; Pugh et al., 2019). In addition, studies have found that *Bifidobacteria* plays a positive role in improving muscle performance (Ibrahim et al., 2018) and maintaining muscle tone (Jäger et al., 2016a). In addition, the intake of probiotics, such as *Bifidobacteria*, can stimulate the proliferation of beneficial metabolites (such as short-chain fatty acids) of specific microorganisms, thus improving the metabolism, immunity, and barrier function of athletes (Pane et al., 2018).

Athletes' cognition may affect their performance. It has been reported that state anxiety has an impact on the performance of technical sports (Gao and Yan, 2010). State anxiety refers to a kind of anxiety that is short-lived and easily affected by the environment (Walkenhorst and Crowe, 2009). This is due to the pressure brought by the actual situation. Intense competition as well as other factors, such as the mutual restriction relationship between competitors and the immediate awareness of results in sports competitions, has made the anxiety experience very common for athletes during training and competition (Strahler et al., 2010). Previous studies have shown that there is a significant negative correlation between state anxiety and the performance of athletes in technical events (De Pero et al., 2016; Mehrsafar et al., 2019), and an increase in state anxiety will lead to a decline in performance (Walter et al., 2019). It was found that anxiety can inhibit the athletes' automatic behavior (Eysenck et al., 2007).

Furthermore, the study on *Bifidobacteria* found that *Bifidobacteria* has a positive effect on the anxiety state of different populations. Taking probiotics composed of *Lactobacillus helveticus* R0052 and *Bifidobacterium longum* R0175 can significantly reduce the anxiety level of healthy volunteers (Messaoudi et al., 2011); the DASS-42 score of adult healthy women is significantly negatively correlated with *Bifidobacteria* (Taylor et al., 2019), and the elderly can improve the mental state of anxiety and depression by supplementing *Bifidobacteria* and moderate resistance training (Inoue et al., 2018). In addition, taking *Bifidobacteria* can improve anxiety in patients with irritable bowel syndrome or multiple sclerosis (Ma et al., 2019; Salami et al., 2019).

The benefits of probiotics in athletes have been reported, but there are few positive results in terms of cognition and emotion. Sawada et al. found that CP2305 supplementation could improve the anxiety and depression scores of long-distance runners (Sawada et al., 2019). Unfortunately, this study did not discuss changes in exercise performance after probiotics intake. In another study, probiotic intervention successfully reduced the pressure perception of athletes and tested the sports performance of mobilization, but no difference was found (Salarkia et al., 2013). Whether probiotics can alleviate the anxiety of athletes, especially the state anxiety under stress, or the change will affect the performance of sports is what this study aimed to explore. In this study, we selected athletes of technical events (diving) that are greatly affected by state anxiety. According to previous research, state anxiety is related to perceived pressure (Hsu et al., 2019). Therefore, this study conducted 8 weeks of intervention for diving athletes. We designed the stress situation and observed the changes in state anxiety and sports performance of athletes taking *B. animalis* subsp. *lactis* under stress.

## MATERIALS AND METHODS

### Subjects and Procedure

In this study, 21 divers from the Chongqing Sports Technical School were selected. All of them were male and ate and lived together because of the training. The exclusion criteria were as follows: (1) recent use of antibiotics, (2) diarrhea and insomnia in the week before the experiment, (3) habit of taking probiotic supplements, and (4) inability to eat and live with other athletes for personal reasons during the experiment. It should be noted that, due to their age, these athletes have not yet received training on how to relieve pre-competition anxiety.

This study is a single-arm study, which requires athletes to conduct sports performance tests under pressure before, during, and after the intervention, complete the measurement of state anxiety and anxiety before the test, and obtain the athletic performance of athletes. We also measure the gut microbiota of athletes before and after the intervention to compare the changes of gut microbiota. The recipes of the athletes are circulated weekly. We have recorded the recipes of the athletes for a week and submitted them to the Chinese clinical trial center with the code chictr1900024119.

During the experiment, the athletes were preparing for the National Children's Diving Championships in August. This study was approved by the ethics committee of the Southwest University Hospital in Chongqing, China, with the code 201903, and recorded in the Chinese clinical trial center with the code ChiCTR1900024119.

## Supplementary Beverages

The yogurt used in the study (Mengniu Dairy (Group) Co., Ltd.) was rich in *Bifidobacterium animalis* subsp. *lactis* BB-12 ($1 \times 10^9$ colony-forming units (cfu)/100 g), *Lactobacillus bulgaricus* ($1 \times 10^8$ cfu/100 g), and *Streptococcus thermophilus* ($1 \times 10^8$ cfu/100 g) according to the Chinese National Food and Drug Administration domestic health food approval certificate (no.: 2015B0306). Considering the age of the participants, the daily intake was recorded by the experimental personnel to ensure the intake compliance rate.

## Measurement of Emotion and State Anxiety

The participants' emotions were measured using the Piers–Harris Children's Self-Concept Scale (PHCSS). The scale was developed by American psychologists Piers Harris and DBEV in 1969 and revised in 1974. This scale is mainly used to evaluate children's self-awareness. There are 80 items in total, which can be divided into six subscales: behavior, intellectual and school status, physical appearance and attributes, anxiety, popularity, and self-contentment (Alexopoulos and Foudoulaki, 2002). In the study of different types of adolescents in China, the anxiety subscale of the scale shows good discrimination, reliability, and validity (Li et al., 2010; Huang et al., 2016; Zhao et al., 2016). In this study, the anxiety subscale was selected, with 14 items in total. In this study, the test–retest reliability of the PHCSS was 0.804.

The state anxiety of the competition situation was measured with the Mental Readiness Form-3 (MRF-3). MRF-3 is composed of three parts, and each part is a 100-mm straight line. The two ends of the body anxiety line represent "worried–not worried," while those of the cognitive anxiety line represent "tense–not tense" and those of the state self-confidence line represent "confident–unconfident." According to the actual situation, athletes marked their own suitable situations on the line. This scale had a high homogeneity with the commonly used Competition State Anxiety Inventory-2 (CSAI-2), among which the consistency coefficients with CSAI-2's body anxiety scale and cognitive anxiety scale were 0.69 and 0.76, respectively (Mesagno et al., 2019). In this study, only the physical and cognitive state anxieties of athletes were measured.

The athletes are asked to attend a meeting before measuring their performance in a simulated real game (see the details in "Section 2.5"). The purpose is to further arouse the athletes' pre-competition anxiety. The athletes were asked to fill in the questionnaire immediately after the meeting. All questionnaires were completed in the Diving Hall of Chongqing Sports Technical School.

## Analysis of Gut Microbiota

### Sample Collection and DNA Extraction

Fecal samples were collected at the Affiliated Hospital of Southwest University and frozen at −80°C within 3 h of sampling. DNA extraction was performed using a QIAamp Fast DNA Stool Mini Kit (Qiagen, CA, United States). The concentration of bacterial DNA was measured using a NanoDrop 2000 spectrophotometer (Thermo Scientific, Waltham, MA, United States).

### High-Throughput Sequencing

The bacterial communities in the fecal samples were investigated by Illumina MiSeq high-throughput sequencing. The V3 and V4 regions of the 16S rDNA gene were selected for PCR. The primers were barcoded as 338F (5′-ACTCCTACGGGAGGCAGCAG-3′) and 806R (5′-GGACTACHVGGGTWTCTAAT-3′), where the barcode was an eight-base sequence unique to each sample. The 20-μl PCR reaction mixture was composed of 4 μl of 5 × FastPfu buffer, 2 μl of 2.5 mM dNTPs, 5 μM each of forward and reverse primer, 0.4 μl TransStart Fastpfu DNA Polymerase (TransGen Biotech, Beijing, China), and 10 ng DNA template. The following cycling parameters were used: maintenance at 95°C for 2 min, 27 cycles of 95°C for 30 s, 55°C for 30 s, and 72°C for 30 s, and a final extension at 72°C for 5 min. Triplicate reaction mixtures were pooled for each sample, purified using an AxyPrep DNA gel extraction kit (Axygen, Union City, CA, United States), and quantified using a QuantiFluor-ST fluorescence quantitative system (Promega, Madison, WI, United States). Amplicons from different samples were sent out for sequencing on an Illumina MiSeq platform at Shanghai Majorbio Bio-Pharm Technology Co., Ltd. (Shanghai, China).

### Processing Sequencing Data

Raw FASTQ files were demultiplexed and quality-filtered using Quantitative Insights Into Microbial Ecology (QIIME) (version 1.9.1) with the three criteria mentioned in Song et al. (2017). Operational taxonomic units were clustered with a 97% similarity cutoff using UPARSE (version 7.12), and chimeric sequences were identified and removed using UCHIME. The taxonomy of each 16S rRNA gene sequence was analyzed using the RDP classifier against the Silva (SSU128) 16S rRNA database using a confidence threshold of 70%. Relevant data from the gut microbiota were uploaded to the National Omics Data Encyclopedia (NODE[1], Sample ID: OEP001026).

[1] https://www.biosino.org/node/

## Simulations of Real Competition

Stress can lead to an increase in state anxiety in athletes. Since the competition field is not open to researchers, it is impossible to measure the anxiety levels of the athletes in a real competition environment. Geukes et al. stated that the use of simulations of real competitions was a better alternative (Geukes et al., 2013). Therefore, this study constructed a scenario to simulate a real competition (stress situation). In this scenario, the pressure setting referred to the research of Wang et al. (2018). We chose the external (referees, spectators) and internal pressures (enhance the athletes' attention to the game) to wake the state anxiety of athletes. We scheduled the test on the last day of week 0, week 4, and week 8 to ensure that the time between each test was equal. Each test is aimed to evaluate the mental state first and then to evaluate the sports performance. All exercise performance tests under stress were performed at the Diving Hall of Chongqing Sports Technical School.

In addition to simulating the competition situation, we also counted the athletes' performance during training. Training situations are considered less stressful. This study aimed to eliminate the possible effect of long-term training on the results of this study.

## Sports Performance

To avoid the ceiling effect, after communicating with the coach, four basic movements in the juvenile diving competition were chosen as the basis for measuring the athletes' performance. In this study, we invited three national referees to score the performance of the diving athletes in the simulation competition. The scoring standard was consistent with that of an official competition (the full score was 10, and the average score of the three referees was the final score). The athlete will know the referee's score the first time after finishing the movement.

## Data Analysis

We did not assume that our relatively small sample had a normal distribution and used the values of our samples without transformation for the purpose of enabling a clear interpretation. We used the Wilcoxon rank sum test to analyze the scale scores and sports performance at different times. Sobs, Shannon, Simpson, Ace, Chao index, and principal coordinate analysis (PCoA) were performed using QIIME 1.9.1 (Mitter et al., 2017). The Wilcoxon rank sum test was used to measure the differences in gut microbiota between groups. Benjamini and Hochberg's false discovery rate (FDR) was used to adjust the results, and significant associations were considered below an FDR threshold of 0.05 (CI bootstrap 0.95). Statistical analysis was carried out using GraphPad Prism V8.3.0 (La Jolla, CA, United States), R statistical package (V.3.6.3).

# RESULTS

## Physical Activities of the Participants

The characteristics of the athletes are shown in **Table 1**. During the experiment, there was no loss of participants, and no reports of adverse events due to probiotic yogurt were reported. The compliance of the participants is reflected by the test drink intake rate in the table. In 8 weeks, the athletes trained every day, and the training plan was recorded by the coaches. Since diving athletes were not allowed to carry wearable equipment to measure the activity during training, the experts were invited to review their training plans to ensure that there was no impact on the results of this experiment due to excessive exercise.

## Effects of *B. animalis* subsp. *lactis* on Mental State

The results of the questionnaires are summarized in **Table 2**. During the experiment, the athletes participating in the experiment were preparing for the National Junior Diving Championships in August. A simulation match was designed on week 0, week 4, and week 8 to collect the state anxiety and emotion of athletes under stressful conditions. MRF-3 was used to evaluate the state anxiety of athletes, and PHCSS was used to evaluate emotions. The changes in the athletes' mental state are shown in **Figure 1**. Compared to week 0, the cognitive state anxiety of athletes significantly reduced at week 4 ($Z = -3.964$, $P < 0.001$), and the somatic state anxiety significantly reduced at week 8 (somatic: $P = 0.003$; anxiety: $Z = -3.079$, $Z = -2.973$, $P = 0.002$).

## Effects of *B. animalis* subsp. *lactis* on Gut Microbiota

The α diversity index can reflect the richness and diversity of the microbial community. In this study, we analyzed the gut microbiota α diversity of the athletes before and after the intervention, and the results are shown in **Table 3**. There was no significant difference in several common α diversity indices before and after the intervention.

**TABLE 1** | Characteristics of the subjects.

| Parameters | Participants |
|---|---|
| Age (years) | 9.10 ± 1.80 |
| Height (cm) | 137.34 ± 9.68 |
| Body weight (kg) | 30.23 ± 5.04 |
| BMI (kg/m$^2$) | 15.93 ± 1.35 |
| Exercise years | 3.90 ± 1.00 |
| Test drink intake rate (%) | 94.30 ± 3.30 |

*BMI, body mass index; cm, centimeter; kg, kilogram.*
*Values are represented as mean ± SD.*

**TABLE 2** | Results of Mental Readiness Form-3 (MFR-3) and Piers–Harris Children's Self-Concept Scale (PHCSS).

| Questionnaire | Week 0 | Week 4 | Week 8 |
|---|---|---|---|
| Somatic (MRF-3) | 6.76 ± 0.80 | 6.44 ± 1.29 | 6.15 ± 0.80 |
| Cognition (MRF-3) | 7.62 ± 0.84 | 5.38 ± 1.16 | 4.30 ± 0.71 |
| PHCSS | 6.19 ± 1.80 | 5.57 ± 1.75 | 5.10 ± 1.37 |

*Values are represented as mean ± SD.*

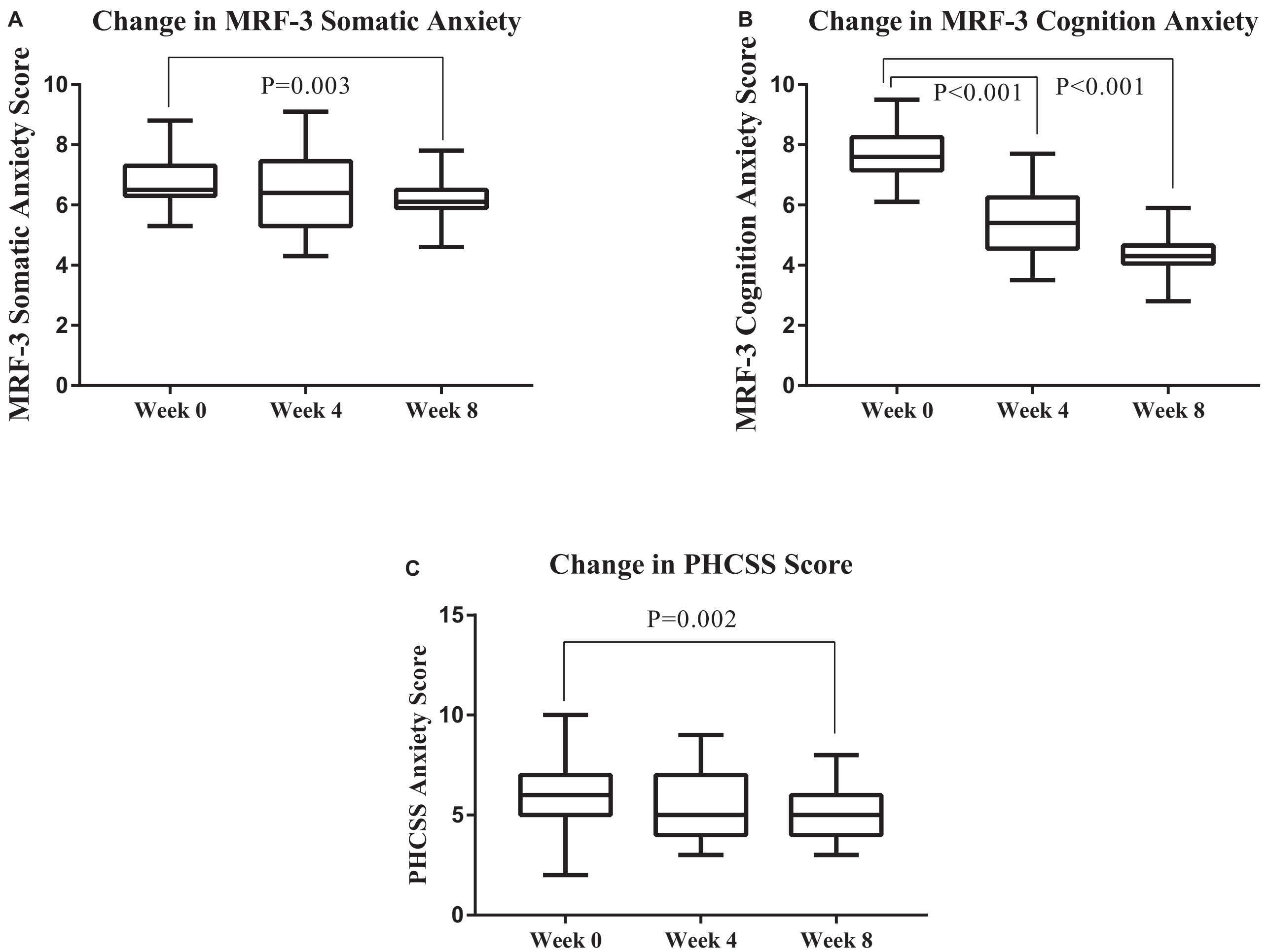


**FIGURE 1 |** Effects on the changes of mental state during the experimental period as determined by questionnaires; somatic anxiety score **(A)**, cognitive anxiety score **(B)**, and anxiety emotion score **(C)**. Data were analyzed using Wilcoxon matched-pairs signed-ranks test between the groups and the *p*-value is shown in each panel.

For the β diversity of the gut microbiota of the athletes before and after the intervention, PCoA was selected for analysis, and the results are shown in **Figure 2**. Before and after the intervention, there was no significant difference in the composition of the gut microbiota community.

**Figure 3** shows the differences before and after the intervention. At the family level, the abundance of *Bifidobacteriaceae* in athletes after the intervention was significantly higher than that before the intervention ($P = 0.05$).

**TABLE 3 |** Test results of α diversity index.

| Estimators | Week 0 | Week 8 | *P*-value | *Q*-value |
|---|---|---|---|---|
| Sobs | 35.33 ± 6.51 | 37.19 ± 6.06 | 0.412 | 0.495 |
| Shannon | 1.68 ± 0.36 | 1.82 ± 0.27 | 0.268 | 0.495 |
| Simpson | 0.30 ± 0.11 | 0.24 ± 0.08 | 0.092 | 0.495 |
| Ace | 44.57 ± 13.09 | 44.92 ± 10.11 | 0.725 | 0.725 |
| Chao | 40.45 ± 10.31 | 42.23 ± 8.25 | 0.372 | 0.495 |

*Several common α diversity index results are listed in the table. Values are represented as mean ± SD. The Q-value represents the false discovery rate value.*

Linear discriminant analysis effect size (LEfSe) analysis was used to test the abundance difference of gut microbiota at different levels before and after intervention. It was found that, after 8 weeks of yogurt intake, the abundance of *Parasutterella*, *Lachnospiraceae*, and *Propionibacteriaceae* also changed significantly. The results of the LEfSe analysis are shown in **Figure 4**.

## Effects of *B. animalis* subsp. *lactis* on Athletes' Performance

The performance of the athletes under stress is shown in **Figure 5**. At weeks 0, 4, and 8, the performance tests under simulated real-competition environment and training environment were conducted. To show that the enhancement of athletes' sports performance in simulated competition was not related to the accumulation of training, we also reported the sports performance scores in the training situation. It can be seen

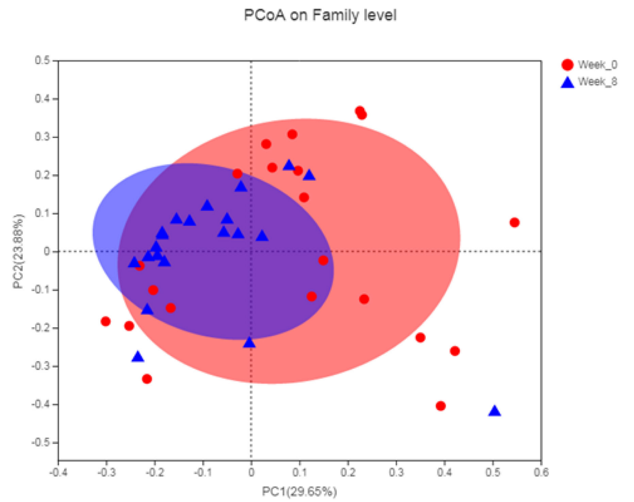


**FIGURE 2 |** Analysis of β diversity of gut microbiota in athletes before and after intervention.

in **Figure 5** that, at the end of the experiment (week 8), the performance in the simulation competition was closer to that of the training environment. Furthermore, Friedman test was conducted on the difference between the training and simulated competition situations. The results are shown in **Figure 6**. There were significant differences in sports performance at different time points ($\chi^2 = 7.88$, $P = 0.019$), indicating that, with the extension of time, the sports performance of athletes in the simulation competition gradually tended to be consistent with the training situation.

## DISCUSSION

Under stress, exercise performance will decrease due to the increase of state anxiety. This phenomenon has been noticed by many researchers. When studying the influence of quiet eye training on the performance of golfers, Samuel et al. found that a stress situation can lead to an increase of state anxiety and a decline of golfers' putt performance (Vine et al., 2011). Wilson et al. found that, under a pressure situation, football players are more likely to pay attention to the existence of goalkeepers, which leads to an increase of perceived anxiety and a decrease of shooting accuracy (Wilson et al., 2009). It should be pointed out that the anxiety of the athletes decreased at week 8, which may be affected by the habituation effect. Although this kind of simulation competition is not created for the purpose of research alone, that is, when there is no intervention, they will hold simulation competition regularly to observe the recent research results. However, we did not collect the anxiety state of the athletes participating in a simulation competition in other periods, so we cannot exclude the influence of habituation effect.

In this study, we tried to observe the change of athletes' state anxiety and its effect on sports performance through the intervention of probiotics. The results show that both somatic state anxiety and cognitive state anxiety are reduced from the previous serious anxiety level to the middle and low anxiety level after intervention, and the performance of the athletes under stress situation has been improved. This shows that the improvement of anxiety will have a positive impact on the performance of the athletes. There are many theories to explain the relationship between sports performance and state anxiety. According to the Attention Control Theory, anxiety interferes with the inhibition and refreshing of the central executive system of athletes' working memory so as to affect the performance of athletes (Mullen et al., 2005).

In real life, due to the need for long-term training, the diet of athletes is often controlled, which leads to a decrease in the abundance of probiotics in the gastrointestinal tract (Jang et al., 2019) and may also lead to a decrease in the α diversity of the gut microbiota, which will increase the risk of the athletes to suffer from gastrointestinal diseases (Clarke et al., 2014). The diversity of the gut microbiota has been shown to be positively correlated with cardiopulmonary fitness (Estaki et al., 2016). Taking yogurt containing probiotics can not only enhance the sense of fullness and avoid overeating but can also improve the probiotic abundance in the body (Zhang et al., 2019). In this study, yogurt containing probiotics was used to intervene in the gut microbiota of athletes. This study explored the effect of *B. animalis* subsp. *lactis* on athletes' perceived anxiety and performance under stress. Diet is an important factor in this type of research. In this study, the athletes of Chongqing diving team were recruited. They stayed together and ate three meals a day in the canteen of Chongqing Institute of Sports Technology. We have recorded the athletes' daily recipes, but we still cannot rule out the impact of diet on gut microbiota because we do not record every athlete's daily diet choice. To avoid the influence of very few samples on the reliability of the experiment, instead of a double-blind, randomized, and placebo-controlled clinical trial, a single-arm study was selected.

After 8 weeks of probiotic supplementation, some changes could be seen in the gut microbiota of the athletes. We found that the supplementation of *B. animalis* subsp. *lactis* did not change the α and β diversity of the gut microbiota in the athletes, but it improved the abundance of *Bifidobacteriaceae* in the athletes. A change in the gut microbiota may affect an individual's mood. Many studies support that the supplementation of probiotics results in the improvement of anxiety in college students, obese people, and candidates under stress (Hadi et al., 2019; Nishida et al., 2019; Tran et al., 2019). A study in 2018 showed that probiotics could improve the cognitive function of athletes during off-season endurance training (Carbuhn et al., 2018). Luna et al. stated that probiotics could affect the gut microbial community, affecting the pathway of the microbial community to the brain, thus affecting cognition and behavior (Luna and Foster, 2015). When athletes are under pressure, the gastrointestinal tract releases hormones, such as gamma-aminobutyric acid (GABA) and short-chain fatty acids (SCFAs), to participate in the regulation of the hypothalamic–pituitary–adrenal axis (Clark and Mach, 2016). State anxiety is affected by the force of stress. Fond et al. suggested that probiotics could interact with the gut–brain axis to regulate the effect of

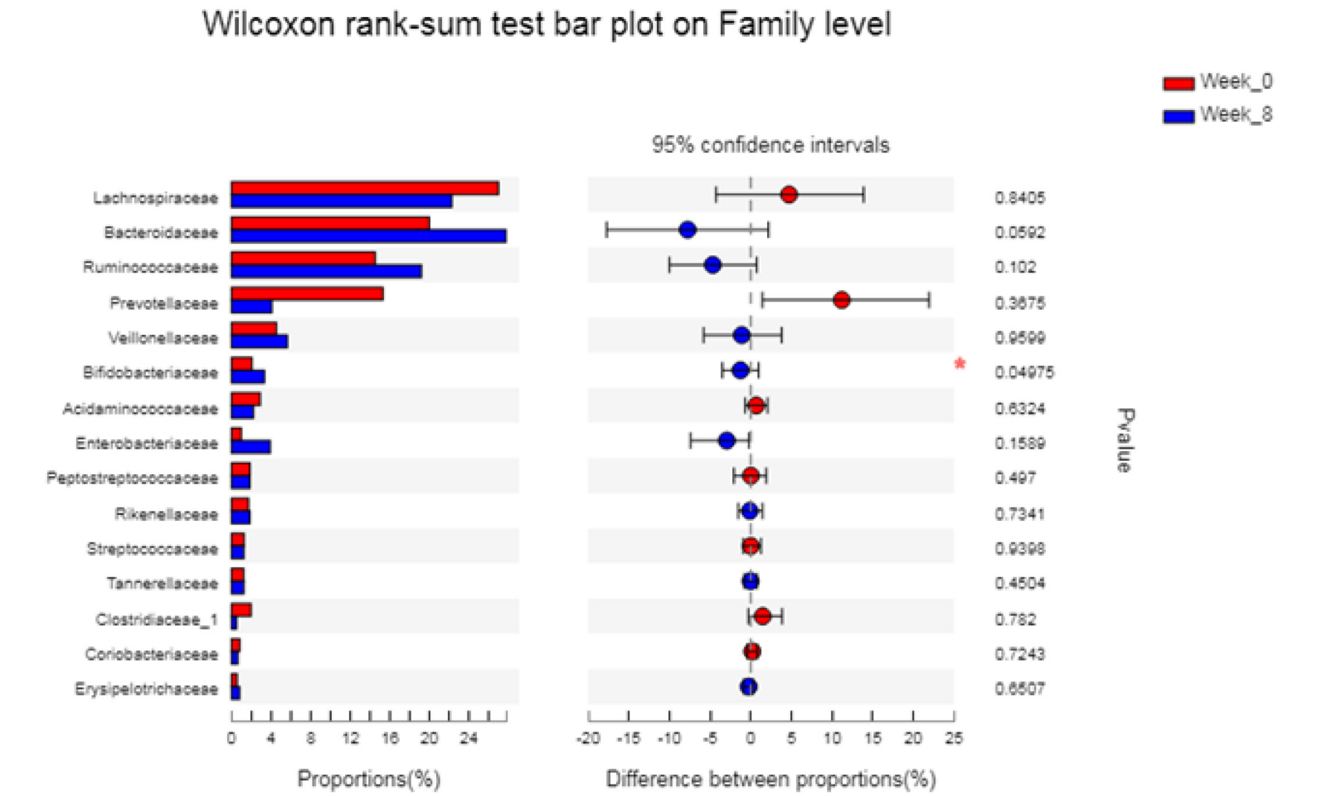


**FIGURE 3 |** The differences between the groups of gut microbiota. The vertical axis (left) shows the name of the bacteria at the family level. Each column that corresponds to a family represents the average relative abundance of each family in each sample group, and different colors represent the different groups. The middle area represents the difference in abundance percentage between the two groups within the set confidence interval. The colors of the dots represent the groups in which family abundance occupies a large proportion. The I interval on the dot represents the upper and lower limits of the difference. *$p < 0.05$.

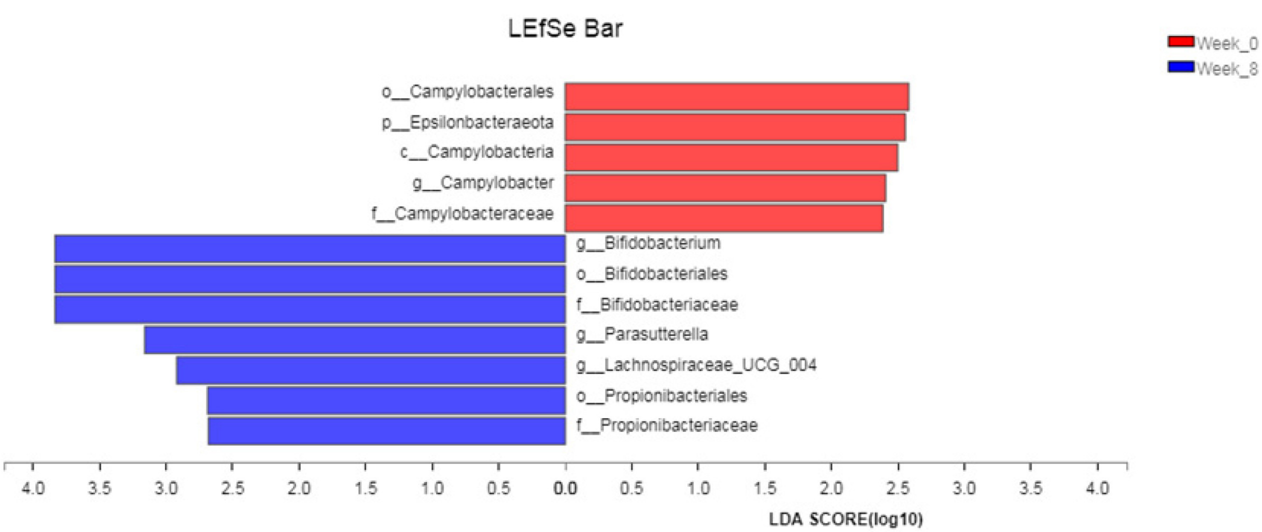


**FIGURE 4 |** LEfSe Analysis. The LDA threshold is set to 2, and one against all (less strict) is selected for multi group comparison.

stress on gut microbiota (Fond et al., 2015). Probiotics are not only related to the production of SCFAs (Pane et al., 2018) but have also been shown to reduce the mRNA expression of the GABA receptor and c-fos in the brain by regulating the gut–brain axis *via* the vagus nerve pathway (Kato-Kataoka et al., 2016). Many studies have shown that probiotics can

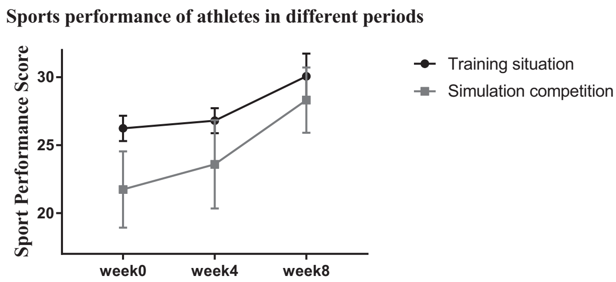


**FIGURE 5 |** Broken line chart of athletes' performance under different pressures. week0 Training situation: 26.24 ± 0.93, Simulation competition: 21.74 ± 2.81; week4 Training situation: 26.80 ± 0.92; Simulation competition: 23.59 ± 3.25; week8 Training situation: 30.07 ± 1.67; Simulation competition: 28.32 ± 2.40.

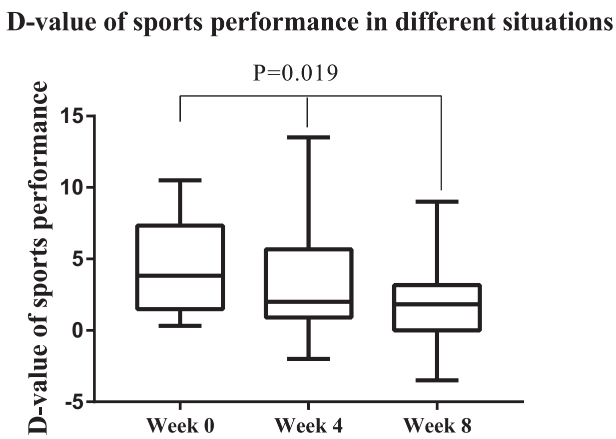


**FIGURE 6 |** Changes of *D*-value of sports performance in different situations. *D*-value = Training situation score minus Simulations of real competitions score.

regulate brain function and stress state (Takada et al., 2016; Molina-Torres et al., 2019).

This study focused on the improvement of sports performance of athletes after taking probiotics. In strength training, the consumption of protein leads to an increase in hydrogen sulfate, which may damage intestinal health (Jäger et al., 2016b). The intake of probiotics can directly improve the health status of athletes and indirectly improve their performance (Leite et al., 2019). In addition, supplementation of probiotics can improve the oxidative stress of triathlon athletes and their sports ability (Michalickova et al., 2018; Huang et al., 2019). However, most of these results are based on the physiological conditions of the athletes, and the conclusion of sports performance is speculated. In this study, probiotics could improve the state anxiety of athletes. With the decrease in state anxiety, the performance of athletes in simulated competition improved. Here we emphasize the influence of anxiety on sports performance. Diving is a kind of technical project that requires a highly technical action (Xu et al., 2010). In such sports, the pressure causes the athletes to focus more on the process of sports, consciously control the execution process of sports, try to improve the efficiency of completing actions, and lead to the execution process that has formed automation to be blocked (Wang, 2004).

In this study, we improved the state anxiety of athletes under stress by regulating the gut microbiota and observed that, with the decline of state anxiety, the performance of simulated competition gradually improved, which enriched the related research on probiotics and sports performance. For technical events, the performance of sports is significantly related to the level of anxiety of the athletes. However, this study was not a randomized controlled trial, and anxiety was measured by subjective self-report. Another drawback is that only microbial diversity analysis was conducted for gut microbiota, not metagenome and metabonomics analysis. In future research, we should design randomized controlled trials, include more volunteers, collect physiological data related to anxiety (such as salivary cortisol), and perform metagenome or metabonomics analysis of the gut microbiota to clarify how probiotics affect athletes' anxiety under stress.

## CONCLUSION

In summary, this study showed that the daily intake of *B. animalis* subsp. *lactis* was effective in reducing the state anxiety of athletes and could improve the performance of athletes under stress. In addition, the intake of *B. animalis* subsp. *lactis* increased the abundance of *Bifidobacteriaceae* in athletes. This study demonstrated the potential of probiotics to improve mental state and performance in athletes under stress.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Southwest University Hospital Ethics Review Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

WD, LP, and GS conceptualized and designed the research. WD and YW performed the experiments. WD and SL analyzed the data. WD and GS plotted the figures. WD drafted the manuscript. All the authors interpreted the experimental results, edited and revised the manuscript, and approved the final version. All measurements were performed at Chongqing Institute of Sports Technology, Chongqing, China.

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# High-Intensity Interval Exercise: Methodological Considerations for Behavior Promotion From an Affective Perspective

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High-intensity interval exercise and high-intensity interval training (HIIT), an exercise approach alternating short bouts of vigorous exercise with less intense recovery or rest periods, has been rated as a leading fitness trend, ranked between #1 and #3 in the annual survey of "Top 20 Worldwide Fitness Trends" since 2014, with no sign of weakening "popularity" (Thompson, 2019). This increased popularity in HIIT programs has been mirrored by a subsequent uptick in related research. In such investigations, HIIT appears to deliver important physiological benefits (much like those observed by any regular exercise behavior; Kilpatrick et al., 2014; Jelleyman et al., 2015). However, little is known about why high-intensity interval programs have gained such popularity within the fitness industry (i.e., increasing number of high-intensity interval type franchises such as F45® Training, Orangetheory Fitness®, Crossfit® Training, Bootcamps, and so on), let alone, and perhaps most importantly, whether such a regimen encourages prolonged exercise[1] behavior (i.e., adherence). Based on previous work (e.g., Williams et al., 2008) with continuous exercise, the affective experience of such HIIT-type programs may be a particularly important reason why it is popular. Thus, we will address some methodological concerns pertaining to HIIT research, specifically related to the study of affective states. We will also propose potential solutions for investigating such psychological phenomena associated with this popular exercise regimen.

## DISENTANGLING HIIT TERMINOLOGY

HIIT, by definition, utilizes planned intensity and work to rest/recovery ratios in unlimited variations (see Laursen and Buchheit, 2019, **Figure 1** for detail on intensity and design variability). That is, a ratio defined as 1:1 (keeping in mind that numerous ratios can be delineated) may differ in duration (e.g., 30-s work: 30-s rest/recovery; 2-min work: 2-min rest/recovery) and exercise type (e.g., running; cycling; also consider that body weight and resistance circuits often include multiple movements within a single HIIT session). These types of protocols are almost exclusively done in research. A closely related regimen, referred to as HIFT, is defined as a "training style that incorporates a variety of functional movements, performed at high-intensity (relative to an individual's ability), to improve parameters of general physical fitness and performance" (Feito et al., 2018, p. 2).

HIFT is distinct from HIIT in at least two important ways: (a) rest/recovery and (b) intensity. While rest/recovery in research-based HIIT is planned and synchronous, HIFT provides greater

[1] While the field often uses the term "exercise" behavior/promotion, this should be interpreted as physical activity behavior and promotion, not simply exercise. The goal is to increase the total amount of physical activity, which may be accumulated via any bodily movement. Exercise, by definition, is planned, structured, repetitive physical activity that is often performed to improve one or more aspects of health (e.g., physical, mental, and social) and fitness (e.g., cardiorespiratory endurance, muscular strength and endurance, flexibility; American College of Sports Medicine et al., 2018).

autonomy in both rest and recovery. That is, the individual makes the determination of when, and for how long, to rest/recover. Another consideration is whether "high-intensity" is an adequate term to express the intensity performed. Due to the flexibility in high-intensity interval programming, laboratory studies *impose* a range of intensities from just within "vigorous" intensity all the way to "supra-maximal" (Laursen and Buchheit, 2019). However, the fitness communities (e.g., F45® Training, Orangetheory Fitness®, Crossfit® Training, Bootcamps, and so on) applying "high-intensity interval-type" programming encourage the individual to "exercise as hard as you can," which may or may not equate to a physiological index of high intensity (see American College of Sports Medicine et al., 2018, p. 146). It is possible the majority of individuals[2] engaging in leisure- or health-related "interval-type" exercise are most often engaging in ***self-selected, perceived high-intensity (i.e., completely autonomous) interval-type*** exercise. Thus, intensity itself is perceptual in nature and varies during this type of exercise session. As a result, the individual is likely modifying their work-to-recovery ratio, and subsequently their intensity, based on how they are feeling (i.e., their affective experience). It is entirely possible these "interval-type" programs remain a popular form of exercise due to the autonomy in both level of exercise-intensity and rest/recovery, resulting in an affective quality (e.g., less unpleasant) that enhances affective associations toward exercise.

## MAXIMIZING QUALITY OF RESEARCH ON AFFECTIVE RESPONSES

Psychological Hedonism is, stated simply, the idea that human behavior is a result of an innate pursuit of pleasure and avoidance of displeasure (Young, 1952; Rozin, 1999). Indeed, accumulating evidence suggests in-task (i.e., during exercise) affective states (i.e., pleasure vs. displeasure) are associated with an increased likelihood of continued exercise behavior, even up to 6- and 12-months later (Williams et al., 2008; see also Rhodes and Kates, 2015 for a review). While we will not go as far to say hedonics is the only, or even primary, concept to be considered in human behavior, we do implore that ***affective states*** (also considered feeling states[3]) should at least be considered. As Antonio Damasio (1994) eloquently wrote -

> *"Knowing about the relevance of feelings in the process of reason does not suggest that reason is less important than feelings, that it should take a backseat to them or that it should be less cultivated. On the contrary, taking stock of the pervasive role of feelings may give us a chance of enhancing their positive effects and reducing their potential harm (p. 246)."*

With so much yet to learn about feeling states in the context of exercise behavior, the relationship between exercise intensity and affective valence (i.e., pleasure vs. displeasure) has been well-established. Evidence has repeatedly demonstrated the ventilatory threshold (VT) as the biological marker of most importance for influencing ***affective states***, that is, fluctuations in one's affective state reliably occur depending on the exercise intensity relative to the VT. Intensities below the VT elicit very little fluctuation in affective state and result in primarily homogenous in-task pleasure, while exercise intensities above the VT elicit intense fluctuation in affective state and result in homogenous in-task displeasure. More fascinating is the effect of exercise intensity at, or proximal to, the VT. It is within this intensity range where heterogeneity of affective responses exists, with such heterogeneity being attributed to fitness, personality, and other individual differences (Acevedo et al., 2003; Ekkekakis et al., 2005; Box and Petruzzello, 2020).

While yet to be empirically tested, it is likely individuals who regularly engage in (self-selected, perceived) high-intensity interval type exercise (i.e., not in laboratory-based studies) are choosing to perform at an intensity at or proximal to their VT when prompted to "exercise as hard as you can." Again, it is likely the autonomy in exercise-intensity and rest/recovery (adjusting both exercise-intensity and rest/recovery when it feels necessary) allows for more effective affective rebounds. Further, these affective rebounds, occurring immediately following exercise cessation within each of the rest/recovery intervals and at the end of the overall exercise session (see **Figure 1**, revised from Box et al., 2020 to demonstrate interval-exercise affective rebounds), likely result in a different affective response than if intensity or rest/recovery were imposed at pre-planned intervals. Thus, experiencing decreases in pleasure (or increases in displeasure) within successive imposed high-intensity work intervals likely is experienced very differently than when the work-to-recovery intervals are self-selected (i.e., autonomous). Differences in affective responses have been observed with a slight preference toward self-selected vs. imposed continuous exercise (Oliveira et al., 2015), but this has yet to be empirically demonstrated during interval-type exercise.

## CONSIDERATIONS FOR EXPERIMENTAL DESIGN

High-intensity interval exercise is not, nor will any exercise mode ever be, the only solution for increasing exercise behavior. This is not to say that high-intensity exercise research is frivolous; rather quite the opposite. An attempt should be made to best understand how exercise of any variety influences an individual, physiologically ***and*** psychologically, and how the individual chooses and adheres to different modes of activity. We are urging the utmost

[2]Athletes with a goal-directive of performance are likely using technology, providing a physiological index, to assure they are adequately exercising within a high-intensity range.

[3]Feeling states are more commonly referred to as affective states within the literature and consist of three similar, but distinct, components: core affect, emotion, and mood. Core affect is the most basic, consciously accessible feeling state and is considered to reflect both affective valence (i.e., pleasure vs. displeasure) and activation (i.e., reflecting the psychological state of wakefulness). Emotion is an "intense" fluctuation in core affect following an internal or external event, real or imagined, that dissipates in a relatively quick (i.e., seconds) timeframe. Moods are longer in duration (i.e., hours or days), less intense (i.e., degree of fluctuation in core affect), and are distinguished by their onset ambiguity (see Ekkekakis, 2013, Nowlis and Nowlis, 1956, and Russell, 2003 for further detail on affective states).

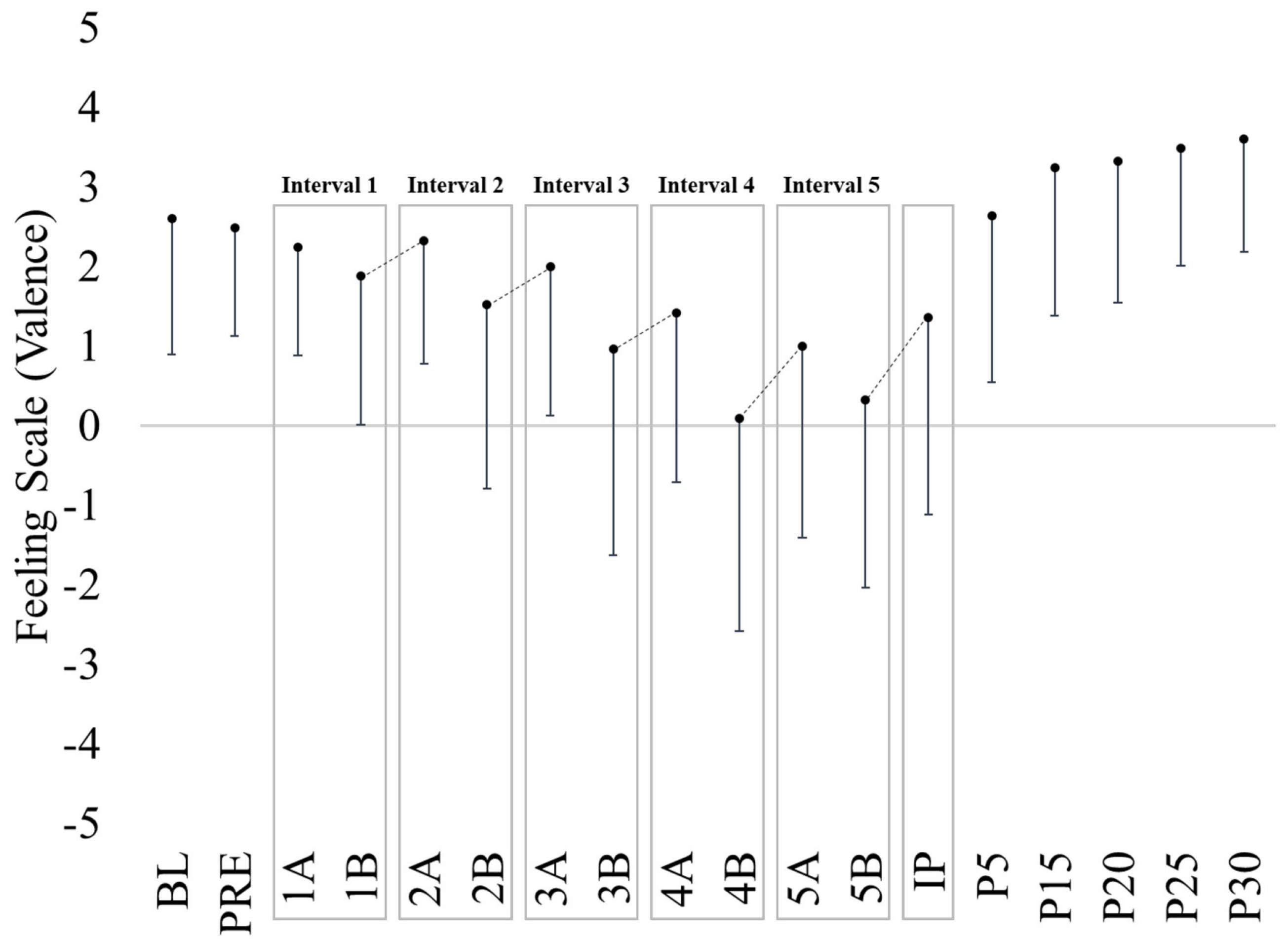


**FIGURE 1 |** Evidence of affective rebound phenomena during interval exercise. The present figure has been adapted from data and figures presented within Box et al. (2020). Regular exercisers ($n = 25$) performed an imposed high-intensity interval exercise on a cycle ergometer (5, 3-min exercise intervals interspersed with 1-min rest) resulting in 75–95% of $HR_{peak}$ throughout the exercise session. Affective valence was recorded within the first (A) and last (B) 10-s of each exercise interval. See Box et al. (2020) for additional experimental design detail. BL, baseline; PRE, immediately prior to exercise while sitting on cycle ergometer; IP, immediately post exercise while remaining on cycle ergometer; P, post exercise. Affective rebounds are delineated by a dashed line.

caution in designing and implementing research to examine such high-intensity, interval type exercise by thoughtfully considering the question at hand, deliberately designing a protocol that unequivocally tests these questions, and transparently interpreting the findings so as not to obscure the answers within.

We strongly encourage the following considerations when examining high-intensity interval-type exercise with an eye toward exercise promotion. We believe the inclusion and transparency of these variables will aid in comparing and interpreting findings across the "interval-type" literature.

We suggest that investigators:

a) ***Appropriately acquire and report a physiological index of intensity (e.g., %$HR_{max}$, %$VO_{2peak}$) and/or total accumulated work***. Given the demonstrated importance of intensity on affective responses, this is a crucial methodological step. The decision of which physiological intensity index is dependent on the research question and experimental limitations, but whenever possible there should not be a sole reliance on perceived exertion.
b) ***Attempt to acquire and quantify VT alongside in-task affect***. The importance of this marker stems from the well-established evidence that affective responses are most aligned with the VT rather than a percentage of maximum heart rate or $VO_{2peak}$. This is important because at the same physiological index of intensity (e.g., %$VO_{2peak}$), one person could be well above their VT and experience the exercise as unpleasant while another person is well under their VT and experiences the exercise as pleasant. Thus, it is more informative to have a participant's in-task affect displayed and interpreted in relation to their VT. This also allows for easier comparisons across studies implementing various interval designs and exercise movements.

c) ***Record affective states during both work and rest/recovery periods along with pre- and post-exercise***. The time-of-assessment should be identical between any compared conditions (especially interval vs. continuous exercise), meticulously designing the assessments to occur *during* exercise for both conditions. The timing should be such that affective states are acquired at least immediately prior to the exercise session (within 1-min), during exercise ***and*** rest/recovery intervals, and immediately post (within 1-min) exercise session. At minimum, affective states should be assessed within the first and last 15-s of each exercise interval and halfway through rest/recovery. Waiting to assess affect until the work bout has just ended will not capture the same affective dynamic as the affective rebound is likely already taking place at that time. Participant reactivity to repeated assessments is also possible when acquiring affective states several times within a short time period, thus forethought is needed to determine how often it is necessary to assess affective states. See Ekkekakis (2013) for suggestions on affective state questionnaires.

d) ***Manipulate only one exercise variable (i.e., intensity, duration, or mode) while standardizing all other variables between testing conditions***. It is necessary, until evidence has been established, to manipulate only one exercise variable to determine whether affective states are a consequence of intensity, duration, or mode. Too often in the high-intensity interval-type vs. moderate-intensity continuous exercise literature all three variables are manipulated, resulting in muddled interpretations. This will likely require multiple experiments in order to confidently provide inferences to a single question, but careful planning that allows for both replication and extension of findings should provide more confidence in the findings.

e) ***Preemptively control, recognize, record, and report possible extraneous variables***. Affective states, by definition, fluctuate moment-to-moment and many variables could unduly influence an individual's affective state data. Consider the lab environment (e.g., decorative pictures, number of research staff, music, unintended conversation, etc.), the researcher's appearance and tone (e.g., white coat affect, provocative clothing, excited vs. bored tone, etc.), the participant's personal items (e.g., cell phone, smart watch, etc.), and so on to eliminate as many potentially confounding sources as possible.

## CONCLUSION

HIIT programs and the numerous variations that have evolved are popular and seem destined to be part of the exercise landscape. Our position in this paper is that we, as exercise behavior researchers, need to exert much greater care in the way that we study these high-intensity interval options. We have outlined what we think are the most critical issues in the design and execution of research, particularly as related to understanding the affective dynamics of such exercise. Given that affect has been shown to be intimately linked with exercise intensity and that affect experienced during exercise is consistently predictive of adherence, careful examination of these affective dynamics in high-intensity interval exercise is crucial. The bottom line is that, as popular as some forms of activity might be, if people do not experience them in such a way that engenders long-term adherence, which is likely if the activity is experienced as unpleasant, it really does not matter what physiological benefits might be gained. We have a lot of work to do to achieve this level of understanding, particularly with high-intensity interval exercise.

## AUTHOR CONTRIBUTIONS

AB was responsible for initial drafting, while both AB and SP equally contributed to the content and draft finalizing. Both authors contributed to the article and approved the submitted version.

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# Measurement of Motivation States for Physical Activity and Sedentary Behavior: Development and Validation of the CRAVE Scale

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Physical activity, and likely the motivation for it, varies throughout the day. The aim of this investigation was to create a short assessment (CRAVE: Cravings for Rest and Volitional Energy Expenditure) to measure motivation states (wants, desires, urges) for physical activity and sedentary behaviors. Five studies were conducted to develop and evaluate the construct validity and reliability of the scale, with 1,035 participants completing the scale a total of 1,697 times. In Study 1, 402 university students completed a questionnaire inquiring about the want or desire to perform behaviors "at the present moment (right now)." Items related to physical activity (e.g., "move my body") and sedentary behaviors (e.g., "do nothing active"). An exploratory structural equation model (ESEM) revealed that 10 items should be retained, loading onto two factors (5 each for Move and Rest). In Study 2, an independent sample ($n$ = 444) confirmed these results and found that Move and Rest desires were associated with stage-of-change for exercise behavior. In Study 3, 127 community-residing participants completed the CRAVE at 6-month intervals over two years- two times each session. Across-session interclass correlations (ICC) for Move (ICC = 0.72–0.95) and Rest (ICC = 0.69–0.88) were higher than when they were measured across 24-months (Move: ICC = 0.53; Rest: ICC = 0.49), indicating wants/desires have state-like qualities. In Study 4, a maximal treadmill test was completed by 21 university students. The CRAVE was completed immediately pre and post. Move desires decreased 26% and Rest increased 74%. Changes in Move and Rest desires were moderately associated with changes in perceived physical fatigue and energy. In Study 5, 41 university students sat quietly during a 50-min lecture. They completed the CRAVE at 3 time points. Move increased 19.6% and Rest decreased 16.7%. Small correlations were detected between move and both perceived energy and tiredness, but not calmness or tension. In conclusion, the CRAVE scale has good psychometric properties. These data also support tenets of the WANT model of motivation states for movement and rest (Stults-Kolehmainen et al., 2020a). Future studies need to explore how desires to move/rest relate to dynamic changes in physical activity and sedentarism.

**Keywords: urge for movement, desire, sedentary activity, physical activity, scale development, motivation, exercise, exploratory structural equation modeling**

## INTRODUCTION

Conditions such as obesity, cardiovascular disease (CVD) and diabetes are all related to a lack of muscular movement and minimal energy expenditure (EE) (Piercy et al., 2018). EE, however, is affected by distinct *behaviors* falling in two dichotomous categories: physical activity (i.e., occupational activity, active transit, exercise) and sedentary behavior (e.g., sitting, watching TV, sleep). These are ostensibly separate but not mutually exclusive constructs, which have independent and interacting effects on health (Owen et al., 2010; Pettee Gabriel et al., 2012; Bull et al., 2020). Recent evidence indicates that humans display substantial variability in the engagement of active and sedentary behaviors. There is also asymmetry in these behaviors. For instance, some individuals achieve high levels of activity, but also high levels of sedentarism (Thompson and Batterham, 2013). Given the distinction between physical activity (PA) and inactivity, growing importance is being placed on understanding the various genetic, neurological, environmental, and psychological antecedents or determinants of these two behaviors (Bauman et al., 2012; Roberts et al., 2012). Motivation appears to be a key intermediary of physically active behaviors. Unfortunately, there is a gap in our current understanding of how the environment and the brain interact to motivate movement and sedentary behaviors, particularly on a *moment-to-moment basis*, which suggests that additional mechanisms may be responsible for their linkage (Bauman et al., 2012).

Research in the area of motivational processes greatly lags behind work in the areas of cognition and emotion, but newer models are reviving older perspectives and synthesizing this with data that suggests that motivated behavior starts with *motivation states*, such as *desires* and *urges* (Robinson and Berridge, 1993; Reiss, 2004; Ferreira et al., 2006; Beeler et al., 2012; Hoffman et al., 2012; Hofmann and Van Dillen, 2012; Hofmann et al., 2012b; Ekkekakis, 2013b; Williams et al., 2019; Stults-Kolehmainen et al., 2020a). Several dual-process models of physical activity have recently emerged- the Affective Reflective Theory of Physical Inactivity and Exercise (ART) (Brand and Ekkekakis, 2018), the model from Conroy and Berry (Conroy and Berry, 2017), the Affect and Health Behavior Framework (AHBF) (Williams and Evans, 2014) and the later Integrated Framework (AHBF-IF) (Williams et al., 2019). All of these models view physical activity and sedentary outcomes as the consequence of interactions between two systems, one responsible for affective processing and one responsible for intentional planning, goal setting and other cognitive processes. Brand and Ekkekakis (2018) incorporate Lewin's (1951) ideas of driving and restraining forces, with the interplay resulting in tensions, which he sees as response to a need, want or some other stimulus, and resulting in an "intention or desire" to carry out a specific task (Marrow et al., 1969). In ART, the affective system operates with automatic processes of stimulus conditioning and hedonic value assessment resulting in an *action impulse*, which is the antecedent to physically active behavior. They also note that "…core affective valence may have a direct, immediate impact on behavior through behavioral urges" (Brand and Ekkekakis, 2018). The Affect and Health Behavior Framework (AHBF) (Williams and Evans, 2014) and its successor, the Integrated Framework (AHBF-IF) (Williams et al., 2019), specifies that the faster, affective system operates on behavior through two intermediaries: automatic motivation (i.e., "wanting," "dread") and affectively charged motivational states (ACMS) (i.e., "craving & desire," "fear") (Kavanagh et al., 2005), which interact with goals and intentions to influence physically active behaviors. A total lack of desire is a hallmark of amotivation as outlined in Self-Determination Theory (Deci and Ryan, 2000; Stults-Kolehmainen et al., 2013b; Rhodes et al., 2019). Finally, in ancient philosophy, Aristotle concluded, "It is manifest, therefore, that what is called desire is the sort of faculty in the [mind] which initiates movement" (Nascimento, 2017; Shields, 2016a,b). Consequently, there appears to be widespread theoretical support for the idea that motivation states for movement, such as wants or urges, propel physical activity.

Given the recent development of most of these theories, however, one needs to cast a wider net across the literature to find empirical evidence of wants and urges to move the physical body. A preponderance of information about desires for movement exists in clinical and psychiatric studies. Urges to move, especially at night, are a defining characteristic of Restless Leg Syndrome, which may affect other parts of the body as well (Garcia-Borreguero et al., 2011; Jung et al., 2017; Ruppert, 2019). Exercise dependence/addiction is a "craving for leisure-time physical activity, resulting in uncontrollable excessive exercise behavior" and showing a variety of physical and psychological symptoms (Hausenblas and Downs, 2002). Long-term use of anti-psychotic medication can result in psychogenic movement disorders, such as tardive dyskinesia and akathisia, the latter of which results in a pressing need to constantly fidget and move about (Iqbal et al., 2007). Dopamine receptor-blocking agents can also induce tardive dyskinesia, which results in an inner urge to move that manifests in chorea, dystonia, akathisia, tics and tremors (Waln and Jankovic, 2013). Aside from these clinical presentations, desires to move may manifest in response to environmental conditions, like upbeat rhythmic music. As an example, *groove* is a state of desiring to move the body in response to a rhythm or harmony (Madison, 2006; Etani et al., 2018; Janata et al., 2018; Levitin et al., 2018; Matthews et al., 2019). Other researchers have identified desires as being specific to fitness, for instance, a desire to gain muscular strength (Katula et al., 2006) or even to generally engage in sport (Hofmann et al., 2012a,b). Even animals clearly demonstrate urges to move when deprived of it, in what is known as *appetence* for muscular motion (Ferreira et al., 2006; Garland et al., 2011). Interestingly, until recently, none of this literature was examined as a unified body of knowledge.

How feelings of urges, wants, desires and cravings for movement, as well as sedentary behavior, relate and differ is addressed by the WANT (Wants and Aversion for Neuromuscular Tasks) model (Stults-Kolehmainen et al., 2020a). In developing this heuristic, Stults-Kolehmainen and colleagues define wants and urges to move as "affectively charged motivation states and associated feelings that signal a pressing need to approach or avoid a state of muscular movement (or, conversely a state of rest)" (Stults-Kolehmainen et al., 2020a). Desires or urges to move might be due to the natural drive to move (Rowland, 1998; Garland et al., 2011; Casper, 2018) which results in tension and is only satisfied when released with movement, which is considered negative reinforcement (de Geus and de Moor, 2011; Stults-Kolehmainen et al., 2020a). In this model, wants and urges for movement and rest are considered separate factors relating orthogonally on two different axes/continua as opposed to opposite poles of the same continuum, similar to a circumplex configuration (Acton and Revelle, 2002). The WANT model specifies that wants/desires to move and rest typify psychological states that are highly transient and change with varying conditions, like physically taxing conditions (e.g., a hard workout), stressful circumstances and conflicting situations when one might be both very tired and also energetic (e.g., having just won a sports competition but also wanting to celebrate) (Thayer, 1978). Where they cross at their 0 points, it is theorized that humans inhabit a deactivated state, perhaps similar to sleep or meditation (Thayer, 1978). Alternatively, the high marks in each direction denote active approach of movement (e.g., during a sports competition) or rest (e.g., crawling into bed). The model also specifies times when there is active avoidance of movement ("diswants"), which might be most obvious in instances of fatigue, illness and injury (Swischuk, 2015), chronic pain and kinesiophobia (Barke et al., 2012). Unfortunately, this model has not been tested rigorously to understand the strength of the association between desires/urges and physically active behaviors (e.g., exercise, sitting time).

At this juncture, intersecting lines of research strongly suggest that humans possess wants/desires for movement and rest behaviors (Iqbal et al., 2007; Beeler et al., 2012; Levitin et al., 2018; Williams et al., 2019; Casper, 2020; Stults-Kolehmainen et al., 2020a). However, a review study in this special issue reports that "little to no research has been conducted to directly measure craving/desire for PA" (Stevens et al., 2020). Most importantly, scientific inquiry to strengthen our understanding of these desires is currently impeded by a lack of validated instrumentation (Rauch et al., 2013; Williams and Bohlen, 2019). Only surveys with only 1–3 items measuring desire or urge for muscular movement-related concepts exist, such as state motivation for specific exercise tasks (Hutchinson et al., 2011), exercise – in general (Pugh and Hadjistavropoulos, 2011), physical activity (Paslakis et al., 2017) or other bodily movement, broadly defined (Sartorius et al., 2012; Casper et al., 2020). Simple measures have also been developed to assess desire to move specifically in response to music (Madison, 2006; Etani et al., 2018; Janata et al., 2018) or desires for fitness (Katula et al., 2006). Some scales refer to wants/desires as a stable construct or trait rather than a state (Lazuras et al., 2017). Some ask respondents to look back retrospectively on their desires and urges rather than in the current moment (Casper et al., 2020). All of these measures lack validation with the exception of a measure to urge to move in the context of akathisia (Barnes, 1989). On the other hand, substantial development of instruments to assess desire, wanting and craving for reward substances, foods and behaviors (Tiffany, 1992; Bohn et al., 1995; Singleton et al., 2000; Sayette and Wilson, 2015) and neurobiological substrates associated with desire and craving states (Sinha, 2013) has occurred.

The primary aim of the current investigation, therefore, was to create and validate an instrument to measure subjective ratings of desire or want, affectively-charged motivation states (ACMS), for physically active behaviors. In accordance with the WANT model (Stults-Kolehmainen et al., 2020a), we also aimed to also assess desires/wants for sedentary behaviors. Our objective was to create a measure of desires/wants that will have acceptable reliability, construct validity, and more specifically, convergent validity. A second aim of this investigation was to test premises of the WANT model, which can be accomplished with the same data and analyses. Based on this framework, we generally hypothesized that: (1) humans have a quantifiable/measurable motivation to move that may be perceived as a desire or want (or in higher levels- urge, craving), (2) desires/wants for movement/physical activity are separable from desires/wants to rest or be sedentary, (3) desires/wants are transitory and possess state-like qualities (i.e., pertaining to processes happening in the moment), (4) motivational states for movement and rest change with relevant provision or avoidance of physical stimuli, such as maximal exercise and a period of rest, and (5) desire to move/rest will be related to, but distinct from, psychosomatic sensations, such as perceptions of physical energy, fatigue, tension and calmness. How these hypotheses are operationalized and link to specific studies 1–5 is described below for each study.

The experimental approach for this investigation was rooted in the classic article on scale development from Clark and Watson (Clark and Watson, 1995, 2019), who assert that construct validity can only be established through a series of studies that involves many observations and may include: examining a factor structure, correlations with other measures, changes over time, changes across an experimental manipulation and differentiations between groups. Consequently, to develop an instrument and test hypotheses related to the WANT model, five total studies were conducted with 4 college-aged populations and 1 community-dwelling sample to psychometrically validate a questionnaire focused on desires/wants for movement/physical activity and rest/sedentarism. In Studies 1 and 2, the scale was developed and distributed, and exploratory structural equation models (ESEM) were conducted. Study 3 followed participants multiple times over a 2-year period with the same scale. Study 4 monitored changes in affectively charged motivation states before and after a treadmill test. Finally, Study 5 administered the questionnaire 3 times over a 50-min lecture period.

## STUDY 1

### Introduction

No validated instrument exists to measure desires/wants for physical activity and sedentary behaviors, despite wide interest from across several literatures, summarized by Stults-Kolehmainen et al. (2020a), a number of non-validated scales in publication (cited above) and calls for a validated instrument to be created (Williams and Bohlen, 2019). The primary purposes of study 1 were to, (a) construct and (b) begin the first steps of validation of a scale for affectively charged motivation states (ACSM; desires/wants) to move and rest. The secondary purpose, as per above, was to test provisions of the WANT model; the first three major hypotheses from above were addressed. For the first hypothesis, it is predicted that participants will rate themselves as having desires/wants for movement and rest, indicated by score means and variability >0 (based on *t*-tests). It is predicted that, for hypothesis 2, an exploratory structural equation model (ESEM) will determine that desires/wants for movement are separate from those for rest (i.e., 2 factors will emerge). However, it could also be argued that additional desire/want factors other than muscular movement and rest may emerge (e.g., a desire or want for *stillness*, an outcome of meditation) (Thayer, 1978; Caldwell, 2004; Devereaux, 2013; Vago and Zeidan, 2016). For the third hypothesis, we predict that desires/wants reported in the current moment ("right now") will significantly vary from those surveyed retrospectively "over the past week" (Casper et al., 2020).

### Methods

**Participants.** A total of 402 college students from a public Midwestern university participated in the first study ($M_{age}$ = 20.9 years, $SD$ = 3.2). Self-reported data revealed that 61.6% of participants were male and 64.9% Caucasian, 17.7% African American, 6% Hispanic/Latino(a), 5% Asian American, 4.7% multiple ethnicities, and 1.5% other/not listed. The academic rank of students was evenly distributed and ranged from a low of 23.1% for sophomores to 26.6% for seniors. Finally, most students (95%) were not athletes on varsity teams sponsored by the university. All individuals signed an informed consent. The study was approved by the Institutional Review Board at Northern Illinois University, in accordance with the Declaration of Helsinki, protocol # HS13-0035.

**Instrumentation.** In addition to a demographic questionnaire, participants completed the Cravings for Rest and Volitional Energy Expenditure (CRAVE) consisting of 30 questions related to the wants/desires or urges individuals had to perform various behaviors or activities. The questionnaire was divided into two identical 15-question parts; the first of which asked participants to respond based on their want/desire to behave in the manners listed *over the past week* (WEEK; PW), while the second was focused on individuals' want/desire to perform the behaviors *at this very moment/Right* now (NOW; RN) (O'Connor, 2004; Terry et al., 2005; Heishman et al., 2009; Casper et al., 2020). Items for each part of the questionnaire were generated by three researchers (MSK, TG and RS) who have research experience in the areas of physical activity, kinesiology, and psychology of addictive behaviors. A process of trimming resulted in 15 acceptable items, seven items related to being physically active (e.g., want/desire to burn some calories; be physically active; exert my muscles; move around etc.) (Casper et al., 2020), while eight items were sedentary behaviors (e.g., want/desire to just sit down, do nothing active, rest my body, etc.). These items were then checked for face validity by four expert scholars (noted for being experts in the field of exercise psychology) from four different institutions who all endorsed the items (JB, JC and two in the Acknowledgments section). Participants responded to each item on an 11-point Likert Scale ranging from 0 = not at all, to 10 = more than ever (Waln and Jankovic, 2013). A full description of the scale development is provided in **Supplementary Table 3**.

**Procedure: data collection.** After receiving Institutional Review Board approval, two researchers from the byline reached out to professors at the selected university who instructed classes of more than 50 students soliciting participation by briefly describing the nature of the study and the approximately 10-min time commitment required. Seven professors agreed to the request and upon the prearranged date/time prearranged date/time one author (TG) traveled to each class for data collection. When addressing the students, the researcher explained the purpose/goals of the study, participants' rights if they elected to participate, and that all data were anonymous. Students were then allowed time to ask any questions or opt out of participation (no student declined participation). Questionnaires were distributed and collected by the researcher and they were completed at the beginning of each class after written consent.

**Data Analysis.** Data were double entered, cleaned for extreme responders (e.g., those who answered all 10s or all 0s on all items), and screened for univariate outliers in SPSS version 26 (Armonk, NY, IBM Corporation). No cases were eliminated due to missing data. As latent factor detection is dependent on covariances (McDonald, 1985), correlations amongst the items were assessed. Since the items were repeated at two time points ("Right Now" and "Past Week"), correlations were conducted at each timepoint separately. Items that showed good stability across both time points (i.e., had significant correlations in both "Right Now" and "Past Week" correlation matrices) were considered for analysis.

Exploratory structural equation modeling (ESEM) (Asparouhov and Muthén, 2009) with repeated time points (for "Right Now" and "Past Week") was employed using Mplus version 8.4 (Los Angeles, CA, United States) (Muthén and Muthén, 1998). The ESEM technique blends exploratory factor and confirmatory analysis strategies by flexibly capturing underlying latent constructs without *a priori* hypotheses on exactly how items will load (Tóth-Király et al., 2017). ESEM therefore has an advantage over traditional EFA as it allows for testing of specific hypotheses of latent constructs while overcoming the cross-loading constraints in CFA (Marsh et al., 2014). It is also recommended over traditional factor analysis for validating exercise psychology instruments (Perry et al., 2015). Two theoretical latent factors were anticipated ("desire to move" and "desire to rest"). Model fit indices for good fit were set to at least 0.9 for TLI and CFI, and less than 0.08 for RMSEA and SRMR (Hooper et al., 2007; Kenny, 2015; Asparouhov and Muthén, 2018; Maydeu-Olivares et al., 2018). To test for reliability of the scale, McDonald's ω was calculated based on factor loadings (McDonald, 1999; Suárez-Colorado et al., 2020). Data were also examined for multivariate outliers using log likelihood contribution plotted against latent factor scores (Muthén, 2010). Outliers were removed and models were re-run to determine if they affected model fit. To test hypothesis 1, given satisfactory fit of the ESEM model, scores on the CRAVE were then calculated. One sample t-tests (SPSS version 26) were used to determine if participants significantly endorsed the constructs overall.

## Results

Means (SD) for NOW items ranged from 3.18 (3.06) for "veg out" (vegetate) to 5.81 (3.16) for "be physically active." For WEEK, they ranged from 2.78 (2.49) for "be motionless" to 7.32 (2.22) for "be physically active." See **Tables 1**, **2** for descriptive statistics. NOW and WEEK items (i.e., want to "move my body" *right now* versus *in the past week*) were correlated for move ($r$ values = 0.30–0.60) and rest ($r$ values = 0.41–0.49).

Correlations amongst the "Right Now" items were all significant. However, amongst the "Past Week" version of these items, two had numerous non-significant correlations ("veg out" (vegetate) and "walk about") and were therefore removed from analysis. Three additional items had multiple very low correlations (smaller than absolute value of 0.3) (Tabachnick et al., 2007). These items included "burn some calories," "lay down," and "rest my body." Analysis that included these items (26 in total, 13 for PW and 13 for RN) yielded a marginally poor fitting model (TLI/CFI: 0.83/0.86; RMSEA: 0.11; SRMR: 0.05). However, removal of these three items (20 in total across PW and RN) yielded a well-fitting, consistent, and parsimonious model (TLI/CFI: 0.92/0.94; RMSEA: 0.08; SRMR: 0.04). For the final model, $X^2$ (190) = 6516.7, $p < 0.001$. See **Table 3** for significant loadings. Overall, "Right Now" loadings were stronger, particularly for the "Move" latent factor (0.72–0.92). However, both "Right Now" and "Past Week" displayed the same significant positive loadings onto the anticipated "desire to move" and "desire to rest" constructs. McDonald's ω was very high for these items (0.97 overall), indicating good reliability of the scale. Removal of multivariate outliers slightly improved but did not substantively change model fit; thus, outliers were retained.

Regarding hypothesis 1, one sample t-tests revealed perceptions of desires/wants to move and rest significantly greater than 0 (Means: Move Right Now 28.5, Rest Right Now 18.9, Move Past Week 34.7, Rest Past Week 18.0; $p$'s $< 0.001$), supporting the idea that people do indeed have movement and sedentary-related desires. Further supporting hypothesis 2, Move and Rest (measured "Right Now") were correlated moderately and inversely ($r = -0.78$). The "Past Week" factors for Move and Rest were more weakly correlated ($r = -0.54$). Regarding hypothesis 3, the move factor assessed "right now" correlated moderately with move assessed "in the past week" ($r = 0.51$), and a similar correlation was found for rest ($r = 0.65$). Desire to move and rest scores were calculated for "Right Now" and "Past

**TABLE 1 |** Descriptive statistics (means, SD) and inter-item correlations for original (non-trimmed) CRAVE items assessed "right now" (Study 1 data).

| | | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Move my body | 5.68 | 3.12 | 1 | | | | | | | | | | | | | | |
| 2 | Be physically active | 5.81 | 3.16 | 0.82** | 1 | | | | | | | | | | | | | |
| 3 | Do nothing active | 3.99 | 3.16 | −0.57** | −0.65** | 1 | | | | | | | | | | | | |
| 4 | Just sit down | 4.44 | 3.15 | −0.65** | −0.67** | 0.71** | 1 | | | | | | | | | | | |
| 5 | Burn some calories | 5.59 | 3.1 | 0.60** | 0.68** | −0.49** | −0.50** | 1 | | | | | | | | | | |
| 6 | "Veg out" (vegetate) | 3.18 | 3.06 | −0.27** | −0.31** | 0.34** | 0.33** | −0.20** | 1 | | | | | | | | | |
| 7 | Expend some energy | 5.6 | 2.87 | 0.75** | 0.79** | −0.60** | −0.62** | 0.73** | −0.22** | 1 | | | | | | | | |
| 8 | Be still | 3.89 | 3.06 | −0.65** | −0.66** | 0.70** | 0.73** | −0.54** | 0.41** | −0.63** | 1 | | | | | | | |
| 9 | Be a couch potato | 3.35 | 3.24 | −0.52** | −0.59** | 0.66** | 0.61** | −0.46** | 0.42** | −0.55** | 0.69** | 1 | | | | | | |
| 10 | Walk about | 4.82 | 2.6 | 0.48** | 0.41** | −0.32** | −0.39** | 0.42** | 0.11* | 0.46** | −0.37** | −0.25** | 1 | | | | | |
| 11 | Exert my muscles | 5.64 | 3.07 | 0.73** | 0.80** | −0.60** | −0.59** | 0.67** | −0.25** | 0.79** | −0.59** | −0.52** | 0.45** | 1 | | | | |
| 12 | Be motionless | 3.3 | 3.03 | −0.55** | −0.55** | 0.68** | 0.68** | −0.46** | 0.45** | −0.52** | 0.76** | 0.67** | −0.33** | −0.53** | 1 | | | |
| 13 | Lay down | 5.22 | 3.37 | −0.48** | −0.52** | 0.55** | 0.59** | −0.39** | 0.30** | −0.54** | 0.58** | 0.57** | −0.27** | −0.49** | 0.58** | 1 | | |
| 14 | Rest my body | 5.44 | 3.2 | −0.53** | −0.55** | 0.60** | 0.65** | −0.44** | 0.29** | −0.56** | 0.61** | 0.58** | −0.36** | −0.53** | 0.61** | 0.83** | 1 | |
| 15 | Move around | 5.8 | 2.87 | 0.75** | 0.77** | −0.59** | −0.66** | 0.61** | −0.31** | 0.75** | −0.66** | −0.58** | 0.55** | 0.70** | −0.57** | −0.47** | −0.53** | 1 |

*$p < 0.05$, **$p < 0.01$.

**TABLE 2 |** Descriptive statistics (means, SD) and inter-item correlations for original (non-trimmed) CRAVE items assessed "in the past week" (Study 1 data).

| | | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Move my body | 7.2 | 1.99 | 1 | | | | | | | | | | | | | | |
| 2 | Be physically active | 7.32 | 2.22 | 0.71** | 1 | | | | | | | | | | | | | |
| 3 | Do nothing active | 3.66 | 2.68 | −0.37** | −0.44** | 1 | | | | | | | | | | | | |
| 4 | Just sit down | 4.67 | 2.48 | −0.34** | −0.33** | 0.61** | 1 | | | | | | | | | | | |
| 5 | Burn some calories | 6.62 | 2.74 | 0.36** | 0.51** | −0.28** | −0.14** | 1 | | | | | | | | | | |
| 6 | "Veg out" (vegetate) | 3.55 | 2.73 | −0.16** | −0.15** | 0.21** | 0.31** | 0.09 | 1 | | | | | | | | | |
| 7 | Expend some energy | 6.57 | 2.19 | 0.52** | 0.62** | −0.38** | −0.28** | 0.49** | −0.02 | 1 | | | | | | | | |
| 8 | Be still | 3.49 | 2.41 | −0.40** | −0.43** | 0.52** | 0.57** | −0.21** | 0.36** | −0.33** | 1 | | | | | | | |
| 9 | Be a couch potato | 3.46 | 2.89 | −0.35** | −0.38** | 0.66** | 0.62** | −0.22** | 0.27** | −0.32** | 0.65** | 1 | | | | | | |
| 10 | Walk about | 5.37 | 2.25 | 0.16** | 0.13** | −0.14** | −0.09 | 0.32** | 0.08 | 0.28** | 0.01 | −0.06 | 1 | | | | | |
| 11 | Exert my muscles | 6.77 | 2.46 | 0.54** | 0.68** | −0.39** | −0.3** | 0.50** | −12** | 0.61** | −0.34** | −0.32** | 0.20** | 1 | | | | |
| 12 | Be motionless | 2.78 | 2.49 | −0.36** | −0.43** | 0.56** | 0.58** | −0.25** | 0.29** | −0.34** | 0.66** | 0.66** | −0.06 | −0.31** | 1 | | | |
| 13 | Lay down | 5.65 | 2.6 | −0.20** | −0.19** | 0.50** | 0.53** | −0.15** | 0.22** | −0.25** | 0.46** | 0.54** | −0.14** | −0.23** | 0.50** | 1 | | |
| 14 | Rest my body | 5.9 | 2.48 | −0.15** | −0.14** | 0.45** | 0.47** | −0.13** | 0.18** | −0.18** | 0.41** | 0.46** | −0.12** | −0.17** | 0.41** | 0.82** | 1 | |
| 15 | Move around | 6.83 | 1.88 | 0.51** | 0.59** | −0.33** | −0.23** | 0.48** | −0.05 | 0.54** | −0.26** | −0.34** | 0.29** | 0.56** | −0.27** | −0.18** | −0.15** | 1 |

*$^{*}p < 0.05$, $^{**}p < 0.01$.*

Week" based on the 10-item version (5 items per construct) by summing the raw scores on the items. When comparing Move RN vs. PW (and Rest RN vs PW), Move scores significantly differed [$t(398) = 10.2$, $p < 0.001$]. However, Rest scores did not [$t(395) = 1.4$, $p > 0.16$]. In other words, Move assessed right now significantly differed from move assessed in the past week, but this was not the case for Rest.

## Discussion

Study 1 initiated the development and validation of a scale to measure wants/desires for movement and rest. This process was highly structural: 30 items were generated for the scale (15 "right now," 15 for "past week"), the items were administered to a test population of over 400 participants, the item set was trimmed, the factor structure was analyzed to determine an appropriate number of scale items to occupy each dimension, and relationships between factors were evaluated. The final scale was composed of two parts: Past Week and Right Now- each with move and rest/sedentary subscales. Each subscale, in turn, has 5 items resulting in a range of scores of 0–50 for both move and rest. Reliability of the scale was high, as determined by McDonald's omega.

Results supported all applicable hypotheses, at least partially. Participants rated their desires to move and rest and being greater than 0 and with sufficient variability – in other words, they perceived these desires existed. This is important because some researchers have questioned the conceptual and practical significance of desires/wants to move, describing them as either being minimal, non-existent (Rosa et al., 2015; Cheval and Boisgontier, 2021) or secondary to dread/aversions for movement (Williams and Bohlen, 2019; Williams et al., 2019). Furthermore, in line with the WANT model (Stults-Kolehmainen et al., 2020a), items loaded into two distinct factors, which were moderately and inversely related. This supports the claim of the model that desires/wants for movement/physical activity are separable from desires/wants to rest or be sedentary.

The factors, originally thought of as "move" and "rest," might be more accurately described as "move" and "sedentary." The statistical analysis resulted in the elimination of several items originally thought to be important for the scale, including "rest my body" and "burn some calories." Trimming these items was originally based on low inter-item correlations, but later confirmed by modeling that indicated a worse fit when these items were included. The omission of these two items is somewhat problematic as the intent of the scale was to measure aspects of "rest." Examining the 5 remaining items (do nothing active, just sit down, be still, be a couch potato, be motionless) seems to indicate that this sub-scale is more related to sedentarism than rest, which makes sense from the standpoint that rest might be construed as a process of purposeful recovery or simply breaks from work (Boucsein and Thum, 1997). Furthermore, sleep, rest and sedentary behavior have independent effects on health and body composition (Must and Parisi, 2009).

Another supposition of the model is that desires/wants are transient and state-like, sometimes changing from moment to moment, but at least not being similar to traits. We asked respondents to rate their current desires and to look back and rate them over the last week. Indeed, there were differences between wants/desires for movement as reported "right now" versus in the "past week," as determined by t tests on scale scores. However, this was not the case for rest. Evaluating desires "right now" requires being attuned to and aware of internal states (i.e., interoception) (Craig, 2009). On the other hand, evaluating them over the past week requires retrospectively assessing fluctuations in desires over a 7 day period and ostensibly requires memory, with intensity of sensations and later sensations being in primary focus (Redelmeier and Kahneman, 1996; Hargreaves and Stych, 2013).

There are several limitations to this study- the main ones being that it assessed a population limited to undergraduate college students who were evaluated at only 1 time point. However, these are deficiencies to be addressed in studies that follow. An important delimiter of this investigation is that we did not assess

**TABLE 3 |** Study 1 factor loadings (move and rest) for "Right now" (NOW) and "Past Week" (WEEK) parts of the CRAVE scale.

| A | Item # | Description | Factor loading move | Factor loading rest |
|---|---|---|---|---|
| Now | 1 | Move my body | **0.849** | −0.024 |
| | 2 | Be physically active | **0.918** | −0.006 |
| | 7 | Expend some energy | **0.880** | 0.005 |
| | 11 | Exert my muscles | **0.919** | 0.066 |
| | 15 | Move around | **0.720** | ***−0.151*** |
| | 3 | Do nothing active | ***−0.142*** | **0.701** |
| | 4 | Just sit down | ***−0.200*** | **0.671** |
| | 8 | Be still | −0.104 | **0.791** |
| | 9 | Be a couch potato | 0.004 | **0.799** |
| | 12 | Be motionless | 0.106 | **0.930** |
| Past Week | 1 | Move my body | **0.692** | −0.083 |
| | 2 | Be physically active | **0.838** | −0.048 |
| | 7 | Expend some energy | **0.742** | −0.003 |
| | 11 | Exert my muscles | **0.827** | 0.049 |
| | 15 | Move around | **0.718** | 0.029 |
| | 3 | Do nothing active | ***−0.133*** | **0.664** |
| | 4 | Just sit down | 0.013 | **0.744** |
| | 8 | Be still | −0.039 | **0.766** |
| | 9 | Be a couch potato | 0.004 | **0.828** |
| | 12 | Be motionless | 0.003 | **0.812** |

| B | Move Now | Rest Now | Move Past Week | Rest Past Week |
|---|---|---|---|---|
| Rest Now | −0.78 | – | – | – |
| Move Past Week | 0.51 | −0.29 | – | – |
| Rest Past Week | −0.39 | 0.65 | −0.54 | – |

*Items 5, 6, 10, 13, and 14 were trimmed from these analyses. All latent factor correlations are significant at $p < 0.001$. Bold = significantly positively loaded $p < 0.05$; Bold italics = significantly negatively loaded $p < 0.05$. A. Standardized factor loadings. B. Correlation matrix of latent factors.*

diswants or aversion/dread for movement and rest (Williams and Bohlen, 2019; Williams et al., 2019)- choosing instead to focus on desires/wants. Despite these shortcomings, this study was the first large step in validating a scale to measure wants/desires for physical activity and sedentarism. Overall, these results indicate that the scale has good initial psychometric/structural properties and further evaluation and validity testing is appropriate.

## STUDY 2

### Introduction

In study 1, the factor structure of a new scale to measure desires/wants for movement and sedentarism was established, modeled and analyzed. The primary purpose of study 2 was to determine model fit in a new sample of participants, as replication of models in new samples is frequently problematic (Perry et al., 2015). A further objective was to assess the reliability of the scale and to determine if there were any issues with discriminate validity (i.e., too much overlap between move and sedentarism factors). As with study 1, these analyses allow for further examination of the WANT model (Stults-Kolehmainen et al., 2020a). As such, analyses from this study are applicable to hypotheses 1–3 in the same manner as in Study 1.

Additional purposes of study 2 were to explore how the CRAVE scale varies by gender and age and determine if there is an association of move/sedentary desires with body mass index (BMI). There is a basis to believe that desires/wants to move/rest would vary by gender, as there are numerous studies indicating psychological and motivational differences between men and women (Stults-Kolehmainen et al., 2013a,b, 2014b). It seems plausible that those of younger age may want to move more, especially when considering movement from a lifespan perspective (Willerman, 1973; Han et al., 2008; Roemmich et al., 2008; Stults-Kolehmainen et al., 2013a). Those who are overweight have greater decrements in mood with small increases in workload (Ekkekakis and Lind, 2006), are less likely to adhere to fitness programs (Sperandei et al., 2016), and score higher for amotivation and externally regulated motivation (Hwang and Kim, 2013). Thus, it seems reasonable to hypothesize that those who are leaner might have greater reinforcement for physical activity, and accordingly, greater desires for movement.

Desires/wants for movement may also vary by stage-of-change for exercise adoption, as specified by the Transtheoretical Model of behavior change (TTM) (Prochaska and Velicer, 1997; Marshall and Biddle, 2001; Lutz et al., 2010). The TTM posits that individuals move through five stages-of-change or readiness for health behavior, starting with precontemplation (no intention to be active) to maintenance (meeting a set level of physical activity for 6 months or longer) (Prochaska and Velicer, 1997). Different sets of behavior change processes are primary in each stage, as well as the strength of various psychological attributes. There is an intersecting literature indicating that readiness, particularly a state of readiness, is related to psychological wants/desires (Kruglanski et al., 2014). For instance, Lutz et al. (2010) hypothesized that individuals in the maintenance stage of exercise behavior may simply be more motivated and have greater drive and impulse toward exercise. Indeed, there is some indication that desire might be more relevant for behaviors that are habitual than for those in emerging stages. In other words, desires or wants are more important for maintaining habits, while processes, such as goals, are more important for starting a new habit (Clear, 2018; Greenwood and Fleshner, 2019). Thus, it was hypothesized that those in higher stages of change/readiness for exercise would have stronger desires/wants for movement and lower desires for sedentarism or inactivity.

### Methods

**Participants.** A total of 444 college students ($M_{age}$ = 20.3 years, $SD$ = 2.9) from a public Midwestern university participated. There was no overlap between studies 1 & 2 for participants. Self-report data from the demographic questionnaire highlighted the fact that 59.2% of the participants were female, 39.4%

male, and 1.4% elected not to respond. The ethnic make-up of the sample was diverse; as specifically, 47.5% of the students classified themselves as Caucasian, 28.1% as African American, 8.4% as Hispanic/Latino(a), 7% as Asian American, 0.7% as Native American, 7.4% as multiple ethnicities, and 0.9% as other/not listed. Student academic rank resembled a positive skewness, with freshman accounting for 28.7% of the sample, sophomores = 29.2%, juniors = 29.8%, seniors = 11.8%, and graduate students = 0.4%. Equivalent to Study 1, 95% of participants were not involved in varsity sports at the university; however, using the stage-of-change from the Transtheoretical Model (TTM) to assess exercise engagement, 79.1% of students in the current study either exercised somewhat, exercised regularly for less than six months, or exercised regularly for more than six months. Finally, body mass index (BMI) was also calculated, revealing that the second sample had a BMI of 25.0 kg/m$^2$ (*SD* = 5.2). Men were 25.9 ± 5.2, and women were 24.4 ± 5.2. All individuals signed an informed consent. The study was approved by the Institutional Review Board at Northern Illinois University, in accordance with the Declaration of Helsinki, protocol # HS13-0035.

**Instrumentation.** Similar to Study 1, participants completed a demographic questionnaire – with the only difference being: (a) the inclusion of items for height and weight to calculate BMI and (b) a single question to categorize Transtheoretical model (TTM) stage-of-change related to exercise involvement (Reed et al., 1997; Lutz et al., 2010). Stage-of-change was assessed using the 5-choice approach (Reed et al., 1997; Lutz et al., 2010) with each item representing the five stages. Participants were asked to select a stage based on their current exercise behavior: (a) "I currently do not exercise and do not intend to exercise in the next 6 months" (pre-contemplation), (b) "I currently do not exercise, but I am thinking about starting in the next 6 months" (contemplation), (c) "I currently exercise some, but less than 3 times per week for 20 min or more each time" (planning), (d) "I currently exercise regularly, 3 times a week or more for 20 min or more each time, *but* I have exercised this much for less than 6 months" (action), and (e) "I currently exercise regularly, 3 times a week or more for 20 min or more each time, *and* I have exercised this much for more than 6 months" (maintenance). Students then responded to the identical CRAVE questions (30 items, 15 for "MOVE" and 15 for "REST") used in Study 1.

**Procedure.** Following the procedures employed in the previous study, two researchers again contacted professors at the predetermined university who had enrollments of greater than 50 students in a class. (Note that Study 2 was conducted in the semester immediately following data collection for Study 1; thus, researchers were careful to exclude potentially large classes based on course sequencing to exclude the possibility of recurring participants.) Eight professors agreed to the request for class participation and one researcher from the byline (TG) traveled to each class for data collection. Once again, the researcher explained the nature of the study, the anonymity of responses, allowed time for questions or for students to opt out of participation (no student declined participation), distributed the questionnaires for completion before class, and collected them upon completion. Written consent was obtained from all participants.

**Data Analysis.** Congruent with Study 1, data were double entered, cleaned for extreme responders (i.e., those who answered all 10s or all 0s on all items), and screened for univariate outliers in SPSS version 26 (Armonk, NY, IBM Corporation). In order to confirm latent findings from Study 1, the same exploratory structural equation modeling (ESEM) (Asparouhov and Muthén, 2009) with repeated time points technique was employed using Mplus version 8.4 (Los Angeles, CA, United States) (Muthén and Muthén, 1998). Both the prior identified 13-item and 10-item versions were assessed. In order to test for reliability, McDonald's ω was also calculated based on factor loadings (McDonald, 1999). As in Study 1, model fit indices for good fit were set to at least 0.9 for TLI and CFI, and less than 0.08 for RMSEA and SRMR (Hooper et al., 2007; Kenny, 2015; Asparouhov and Muthén, 2018; Maydeu-Olivares et al., 2018). Data were also examined for multivariate outliers using log likelihood contribution plotted against latent factor scores (Muthén, 2010). Outliers were removed and models were re-run to determine if they affected model fit.

The associations between desires/wants to move and rest and TTM stage-of-change, BMI, age, and gender were explored using multiple linear regressions in the R package (v. 3.6.1, R Core Team, Vienna, Austria). TTM stage and gender were treated as dummy coded factors while BMI and age were entered as continuous variables. Independent variables were all entered in the same step. Wants/desires to move and rest over the "past week" and "right now" encapsulated the four dependent variables. CRAVE scores were derived by summing the 5 items identified in Studies 1 and 2 from relevant subscales. Significance was set to $p < 0.05$.

## Results

Means (SD) for NOW items ranged from 3.06 (3.06) for "veg out" (vegetate) to 6.05 (3.31) for "rest my body." For WEEK, they ranged from 2.31 (2.39) for "be motionless" to 7.53 (2.13) for "be physically active." Therefore, participants indicated that they did perceive desires/wants for movement and rest (hypothesis 1). See **Supplementary Tables 1, 2** for descriptive statistics and correlations for the CRAVE scale items.

Similar to Study 1 results, the 13-item version of the scale displayed a marginally poor fitting model (TFI/CFI: 0.81/0.84; RMSEA: 0.10; SRMR: 0.06). Utilizing the 10-item version previously identified in study 1 (removing "burn some calories," "lay down," and "rest my body") lead to an improved, good fitting model (TFI/CFI: 0.91/0.93; RMSEA: 0.08; SRMR: 0.04). For the final model, $X^2$ (148) = 603.9, $p < 0.001$. Items loaded similarly to Study 1 (see **Table 4**), with interpretable "Move" and "Rest" latent variables in both the Right Now and Past Week timepoints. Removal of multivariate outliers slightly worsened model fit but not did substantively change them (all goodness-of-fit indices within desired parameters); thus, outliers were retained. McDonald's ω was very high (0.97 overall), indicating good reliability of the scale.

In further support of main hypothesis 2, the correlation between Rest-Move factors was inverse and moderate to strong ($r = -0.71$ and $r = -0.55$ for the NOW and WEEK scales, respectively), but not strong enough to suggest a significant discriminant validity issue (where $r > 0.85$) (Mukaka, 2012).

**TABLE 4 |** Study 2 factor loadings (move and rest) for "Right now" (NOW) and "Past Week" (WEEK) parts of the CRAVE scale.

| A | Item # | Description | Factor loading move | Factor loading rest |
|---|---|---|---|---|
| Now | 1 | Move my body | **0.849** | −0.046 |
| | 2 | Be physically active | **0.918** | −0.007 |
| | 7 | Expend some energy | **0.880** | 0.045 |
| | 11 | Exert my muscles | **0.919** | 0.062 |
| | 15 | Move around | **0.720** | −0.025 |
| | 3 | Do nothing active | ***−0.142*** | **0.653** |
| | 4 | Just sit down | ***−0.200*** | **0.667** |
| | 8 | Be still | −0.104 | **0.886** |
| | 9 | Be a couch potato | 0.004 | **0.816** |
| | 12 | Be motionless | 0.106 | **0.875** |
| Past Week | 1 | Move my body | **0.737** | −0.012 |
| | 2 | Be physically active | **0.832** | −0.002 |
| | 7 | Expend some energy | **0.734** | 0.004 |
| | 11 | Exert my muscles | **0.772** | 0.060 |
| | 15 | Move around | **0.674** | −0.043 |
| | 3 | Do nothing active | −0.093 | **0.680** |
| | 4 | Just sit down | 0.024 | **0.717** |
| | 8 | Be still | **0.146** | **0.819** |
| | 9 | Be a couch potato | −0.031 | **0.711** |
| | 12 | Be motionless | −0.008 | **0.788** |

| B | Move Now | Rest Now | Move Past Week | Rest Past Week |
|---|---|---|---|---|
| Rest Now | −0.713 | – | – | – |
| Move Past Week | 0.518 | −0.302 | – | – |
| Rest Past Week | −0.335 | 0.654 | −0.554 | – |

*Items 5, 6, 10, 13, and 14 were trimmed from these analyses. All latent factor correlations are significant at $p < 0.001$. Bold = significantly positively loaded $p < 0.05$; Bold italics = significantly negatively loaded $p < 0.05$. A. Standardized factor loadings. B. Correlation matrix of latent factors.*

In support of main hypothesis 3, the move factor assessed "right now" correlated moderately with move assessed "in the past week" ($r = 0.52$) and a similar correlation was found for rest ($r = 0.65$), indicating participants rated their desires/wants differently over these time intervals. Furthermore, NOW and WEEK items (i.e., want to "move my body" *right now* versus *in the past week*) were correlated for move ($r$ values = 0.34–0.64) and rest ($r$ values = 0.40–0.49).

Multiple linear regression analyses conducted to determine the association between CRAVE constructs (10-item scale for RN and PW) and age, gender, BMI and stage-of-change for exercise were all significant: Move-RN: $F(7, 412) = 5.763$, $p < 0.001$; Rest-RN: $F(7, 413) = 5.65$, $p < 0.001$; Move-PW: $F(7, 418) = 10.02$, $p < 0.001$; Rest-PW: $F(7, 416) = 2.436$, $p = 0.019$. Residuals were all normally distributed. Type III tests found that exercise stage-of-change as a single variable was significant in all four models ($p < 0.001$ in all models except Rest-PW, which was $p = 0.014$). Therefore, stage-of-change was run as 4 categorical variables. Being in the precontemplation or contemplation stages significantly predicted all four CRAVE outcomes ($p < 0.05$). Being in the planning stage was significant in 3 models (Move-RN/PW and Rest-RN; $p < 0.05$). Age only predicted Rest "Right now," $B = -0.555$, SE = 0.230, $t(413) = -2.417$, $p = 0.016$. Gender and BMI did not predict any CRAVE outcome. See **Table 5**.

## Discussion

To further assess the psychometric properties of the CRAVE, 400 + new participants were administered the CRAVE scale (both Past Week and Right Now). Most importantly, the final exploratory structural equation model (ESEM) utilized in Study 1 was replicated with a good fit, indicating the model has good stability across two independent samples (Asparouhov and Muthén, 2018). Furthermore, reliability (internal consistency) of the subscales was very good. Factor loadings generated from the ESEM supported the current model structure and move/rest factors were moderately and inversely related. Thus, problems with discriminate validity were not detected. "Right now" and "Past week" factors were moderately correlated for both move and rest, indicating perceived changes in wants/desires over time. Consequently, it appears that objectives regarding the scale as well as hypotheses specific to the WANT model were all supported.

The most consistent finding from the multiple linear regression analyses was the association of exercise stage-of-change with desires/wants to move and rest. Compared to those in the maintenance stage (consistently exercising for 6 months), those who classified themselves as pre-contemplators (not considering exercise), contemplators (thinking about starting exercise) and those planning to start an exercise regimen rated their desires to move as lower and their desires to rest as higher. The same trend was observed for those in the action stage (exercising inconsistently), though the relationship was not significant. Thus, one might infer that those most habituated to exercise have the strongest desires to move and the lowest desires to be sedentary. This seems to be consistent with observations that wants/desires might be more important for behavior in those who are habitual exercisers (Lutz et al., 2010; Clear, 2018; Greenwood and Fleshner, 2019). On the other hand, cognitive approaches (e.g., goals, intentions) may be more important targets for those wanting to initiate an exercise regimen. It is also possible those in lower stages of change have greater competing desires (e.g., from other pleasurable stimuli), notice their desires for movement less (i.e., are less attentive) are more sensitive to desires to be sedentary (Stults-Kolehmainen et al., 2020a) and/or have desires dampened by external forces or internal states, such as the experience of stress (Lutz et al., 2010). Lesser desires to move and greater desires to rest might contribute to poorer regulation of physical activity in lower stages of change (Sørensen and Gill, 2008), and these data further support the notion that a stage-based approach to behavioral counseling is useful (Blissmer

**TABLE 5 |** Associations of age, gender, BMI and exercise stages of change (Transtheoretical Model) with desires/wants to move and rest, both "right now" and "in the past week"[a].

| | | | | Right Now | | | | | | | Past Week | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Outcome** | **$R^2$ (adj.)** | **Predictors** | **B** | **SE** | **t** | ***p*** | **Model** | **$R^2$ (adj.)** | **Predictors** | **B** | **SE** | **t** | ***p*** |
| | | | Intercept | 31.269 | 5.325 | 5.872 | < 0.001 | | | Intercept | 43.352 | 3.328 | 13.026 | < 0.001 |
| | | | Age | 0.191 | 0.218 | 0.876 | 0.381 | | | Age | −0.161 | 0.136 | −1.181 | 0.238 |
| | | | Gender[b] | −1.576 | 1.365 | −1.155 | 0.250 | | | Gender | −0.907 | 0.853 | −1.063 | 0.288 |
| | | | BMI | −0.098 | 0.121 | −0.804 | 0.422 | | | BMI | −0.007 | 0.076 | −0.092 | 0.927 |
| 1a | Move | 0.074*** | Precontemplation[c] | −12.624 | 4.035 | −3.128 | 0.002 | 1b | 0.129*** | Precontemplation | −13.042 | 2.538 | −5.139 | < 0.001 |
| | | | Contemplation | −9.135 | 2.032 | −4.496 | < 0.001 | | | Contemplation | −6.567 | 1.263 | −5.196 | < 0.001 |
| | | | Planning | −6.259 | 1.729 | −3.621 | < 0.001 | | | Planning | −5.845 | 1.084 | −5.394 | < 0.001 |
| | | | Action | −2.869 | 1.850 | −1.551 | 0.122 | | | Action | −1.671 | 1.154 | −1.441 | 0.150 |
| | | | Intercept | 31.005 | 5.610 | 5.527 | < 0.001 | | | Intercept | 18.828 | 4.200 | 4.487 | < 0.001 |
| | | | Age | −0.555 | 0.223 | −2.417 | 0.016 | | | Age | −0.017 | 0.171 | −0.098 | 0.922 |
| | | | Gender | −0.258 | 1.439 | −0.179 | 0.858 | | | Gender | 0.232 | 1.071 | 0.217 | 0.828 |
| | | | BMI | −0.111 | 0.128 | −0.869 | 0.385 | | | BMI | −0.171 | 0.095 | −1.797 | 0.073 |
| 2a | Rest | 0.072*** | Precontemplation | 14.064 | 4.256 | 3.305 | 0.001 | 2b | 0.023* | Precontemplation | 7.957 | 3.193 | 2.491 | 0.013 |
| | | | Contemplation | 9.910 | 2.137 | 4.638 | < 0.001 | | | Contemplation | 3.298 | 1.600 | 2.061 | 0.040 |
| | | | Planning | 4.631 | 1.823 | 2.540 | 0.011 | | | Planning | 2.665 | 1.362 | 1.956 | 0.051 |
| | | | Action | 3.175 | 1.951 | 1.627 | 0.104 | | | Action | −0.150 | 1.468 | −0.102 | 0.919 |

[a]*Wants/desires are sum scores for each subscale of the CRAVE (range of scores: 0−50).*
[b]*Gender is coded male = 0, female = 1.*
[c]*Maintenance is the reference group for the exercise stage of change construct.*
**Model significant at $p < 0.05$ level. ***Model significant at $p < 0.001$ level.*

and McAuley, 2002). Such possibilities deserve greater attention in the literature.

Against expectations, gender, age, and BMI were largely unrelated to CRAVE scores. Age was linearly associated with rest "right now," with those who were older having less of this desire. However, age was unrelated to other aspects of desire/wants for movement and rest. Perhaps those who have been in college longer have better sleep regulation (i.e., less sleep debt) or are less disrupted by the transition from home to college (Lund et al., 2010). Or perhaps they are less impacted, noticing their desires less or managing them better (Kennett and Reed, 2009). It is also possible that younger college students were taking earlier classes (e.g., 8am) due to university course registration policies. Unfortunately, we could not conduct an analysis by time of day. It would be useful to investigate differences in CRAVE scores among college class levels (i.e., freshmen, sophomores, graduate students).

This study had several limitations that should be considered in future studies. First, the sample included in this study (and in study 1) had a limited range for age and BMI. Inquiry into exercise behavior was limited to stage-of-change, and other aspects of physical activity and exercise behavior should be considered (Bull et al., 2020). We also did not measure any aspect of sleep or resting behaviors, like napping, which are ostensibly impactful on desires to rest and be sedentary and vice versa (Smith et al., 2007). This investigation did not control for time-of-day (e.g., morning, afternoon) or seasonal effects, which likely relate to exercise behavior and motivation to move (Tucker and Gilliland, 2007). The issue of time of day is considered in the following studies below, however. Inclusion of such variables might account for a much greater proportion of the variance in CRAVE scores, whereas in the current models, only a small amount of variance was explained. Despite these shortcomings, results from Study 2 provide further evidence that the CRAVE has good psychometric properties and may be moved forward for further validity testing.

# STUDY 3

## Introduction

The main purpose of Study 3 was to investigate the reliability of the Move and Rest subscales of the CRAVE tool throughout a 2-year time span, as well as within the same day (2 points, pre- and post-of a laboratory session). Study 3 directly tested hypothesis 3 and supported hypotheses 1 and 2. Specifically, we hypothesized that Move and Rest scores would show greater reliability within the same day than across 2 years. These findings would suggest that the desire to move or rest has state-like properties rather than trait-like properties. States are brief, temporary, and easily influenced by changes in the external environment or internal milieu. Meanwhile, traits are stable, long-lasting, and emanate primarily from within the person (Chaplin et al., 1988). A secondary aim, not in the main hypotheses, was to determine which desire was rated stronger – move or rest. This has never been tested before, but one might surmise that humans desire or want rest (including sleep and relaxation) more than movement (including leisure time physical activity and exercise). Hofmann et al. (2012a,b) found that desires to sleep/rest are the most common desires humans have and outrank other desires, such as sports participation.

## Methods

The CRAVE Scale was administered to 127 participants (28.1 ± 7.9 yrs, 47% female) at 0, 6, 12, 18, and 24 months. The 13-item version for "Right now" was utilized as found from

Studies 1 and 2 (10 items scored and 3 are fillers). The ethnic make-up of the sample was diverse, as 42.5% of participants classified themselves as Caucasian, 32.3% as African American, 8.7% as Hispanic, 7.9% as Asian, 7.9% as Other and 0.8% did not report ethnicity. Participants were queried at two time points (i.e., Point 1; Point 2) at baseline and each of the four follow-up sessions. CRAVE scores were collected before and after they completed a battery of self-report and structured interviews that were part of a larger study aimed at understanding the motivation to eat hyperpalatable foods (Sinha et al., 2019).

Statistical tests were performed using R (Version 4.0.2; R Foundation for Statistical Computing, Vienna, AT, United States). Participants completed the CRAVE a variable number of times. Therefore, within subjects test-retest reliability was assessed with an inter-class correlation (ICC) generated with a random intercept model using a linear mixed effects model. Test-retest reliability was assessed for within session (i.e., Points 1 and 2 of the testing session) and between sessions (i.e., at timepoints 0, 6, 12, 18, and 24 months) for Move and Rest subscores. To ascertain the effects of time, both across sessions (Points 1 and 2) and across months (0–24), a linear mixed effects model was created with 3 terms: session time point, month, and an interaction term. All individuals signed an informed consent. The study was approved by the Human Investigation Committee at the Yale School of Medicine, in accordance with the Declaration of Helsinki.

## Results

On average, participants completed the CRAVE 5.4 ± 3.04 times over 24 months. Because the scale was introduced as part of an ongoing clinical trial, the number of observations (Point 1/Point 2) at baseline and 6, 12, 18, and 24 months were 50/36, 61/59, 68/67, 78/74 and 97/96, respectively. Descriptive statistics and within-day correlations and intra-class correlations are presented in **Table 6**. Move was significantly higher than rest for Point 1 of the lab session (25.08 ± 10.9 vs. 17.6 ± 10.8, $p < 0.001$). Move was also higher than rest for Point 2 (end of session) (24.52 ± 11.3 vs. 16.45 ± 11.0, $p < 0.001$). In fact, Move scores were consistently higher than Rest scores at each time point across all 24 months. See **Figure 1**. Move scores taken within the same day (Points 1 and 2) had ICC's = 0.72–0.95, and rest scores taken within the same day had ICC's = 0.69–0.89, indicating at least moderate strength (Koo and Li, 2016). However, across 24-months, move (ICC = 0.53) and rest scores (ICC = 0.49) had lower reliability. Therefore, the CRAVE Scale showed greater test-retest consistency within each day than across 0, 6, 12, 18 and 24-months. A linear mixed effects model revealed that there was no significant effect of session time point (pre/post), but month did trend for significance for both move and rest [Move: ($F(309.69, 1) = 3.6425$, $p = 0.057$); Rest: ($F(314.10, 1) = 3.4905$, $p = 0.063$)]. The interaction term between CRAVE Scores measured across months and within each day was not significant Move: ($F(318.11, 1) = 0.4113$, $p = 0.52$); Rest: ($F(328.55, 1) = 0.0004$, $p = 0.98$).

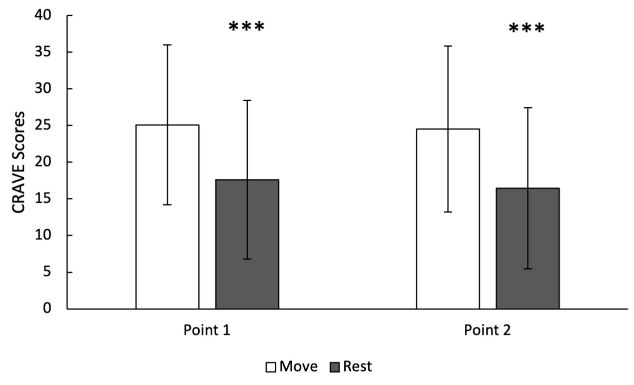


**FIGURE 1 |** Desires/wants to move and rest at Point 1 (pre-lab session) and Point 2 (post-lab) across 24 months of follow up. *** denotes $p < 0.0001$.

## Discussion

The results from Study 3 support the third general hypothesis, that desires to move and rest are transitory and have state-like qualities, as opposed to trait-like properties. This was demonstrated by associations that were significantly greater between the urge to move and rest at two points within the same lab session compared to associations between these desires across multiple months. In other words, there was greater reliability within the same day than across 2 years. These findings are congruent with previous literature demonstrating that the desire to be physically active is not stable and can be affected by a myriad of fluctuating psychological factors,

**TABLE 6 |** Means, standard deviations, Pearson's correlations (r), and intra-class correlations[a] (ICC) for Move and Rest Scores within the same test day (session points 1 and 2) across two years of follow-up[b].

| Time (months) | Move (Point 1) | Move (Point 2) | Move Scores (r) | Move Scores (ICC) | Rest (Point 1) | Rest (Point 2) | Rest Scores (r) | Rest Scores (ICC) |
|---|---|---|---|---|---|---|---|---|
| 0 | 27.4 ± 12.7 | 29.9 ± 10.9 | 0.93 | 0.95 | 17.0 ± 10.1 | 13.8 ± 8.7 | 0.83 | 0.89 |
| 6 | 23.8 ± 10.6 | 22.4 ± 11.9 | 0.74 | 0.72 | 16.2 ± 10.3 | 16.4 ± 11.8 | 0.77 | 0.69 |
| 12 | 25.5 ± 11.5 | 24.2 ± 11.4 | 0.80 | 0.79 | 16.8 ± 10.3 | 16.3 ± 11.2 | 0.88 | 0.86 |
| 18 | 24.2 ± 11.0 | 24.9 ± 11.3 | 0.86 | 0.85 | 19.0 ± 11.2 | 16.7 ± 10.7 | 0.75 | 0.75 |
| 24 | 25.1 ± 9.6 | 23.7 ± 9.8 | 0.82 | 0.82 | 18.2 ± 11.3 | 17.4 ± 11.4 | 0.84 | 0.86 |

[a] *ICC's are derived from a linear mixed effects model that has a random intercept for each participant.*
[b] *Move trended higher over two years (p = 0.057) and rest trended down (p = 0.063).*

such as mood, affect, state anxiety, anger, and stress (Stults-Kolehmainen and Sinha, 2014; Stults-Kolehmainen et al., 2020a). Furthermore, Rowland has proposed that the desire to perform physical activity can be affected by proximal factors such as personal desires, peer influences, and environmental conditions (Rowland, 1998) as well as dietary and pharmacological influences (Stults-Kolehmainen et al., 2020a).

Interestingly, desires to move and rest did not vary across the laboratory session (Points 1 and 2), but there was a trend for move to increase and rest to decrease across two years of time. Such trends might be due to factors, such as aging (Stults-Kolehmainen et al., 2013a) and key experiences (Han et al., 2008; Lund et al., 2010). It could also be caused by reactance and acclimation to the scale itself. Some researchers remove the baseline responses from analyses for this reason (Lutz et al., 2010). [Note: Evidence presented later in Study 5 seems to negate this possibility.]

Of note, participants rated their desires to move higher than their desires to rest at every query point in the study. No formal hypothesis was formulated regarding this finding, but the trend was readily apparent. From an evolutionary standpoint, this might make sense, as movement is required for daily function in life, such as acquiring food, seeking shelter, and play, and behaviors that have such high utility are likely to be wanted (Ekkekakis et al., 2005; Stults-Kolehmainen et al., 2020a). On the other hand, behavior, such as structured exercise, has only recently been reinforced in human history (Lieberman, 2020). Likewise, Hofmann et al. (2012a,b) has found that desires for rest/sleep are the most common desires that participants have, outweighing other desires, such as food, coffee, sex, and sports participation. One might consider that the finding of higher desires for movement compared to rest is due to sampling bias. However, a strength of this study is that it included >600 observations of the CRAVE scale, measured over 2 years in 125 participants from a community-residing sample.

# STUDY 4

## Introduction

The purpose of Study 4 was to investigate changes in the desire to move and rest after a bout of maximal exercise. Indeed, a hallmark of any urge or craving is change in magnitude across time, which sometimes occurs rapidly (Hofmann et al., 2012a; Redden, 2015). In particular, there is typically a reduction in desire once a sufficient quantity or intensity of a relevant stimulus is experienced, in other words, satiation is reached (Redden, 2015). Conversely, during deprivation, desires will increase. Concomitantly, at sufficiently high levels of either satiation or deprivation, the experience may be discomfort and aversive sensations (e.g., feeling "full" or "stuffed" after overeating or famished when without any food) (Redden, 2015; Malagelada et al., 2016). It seems reasonable that the same should hold true for desires for movement and rest in response to varying levels of physical activity and sedentary behavior.

A maximal treadmill test provides an opportunity for both an excess of movement and the physiological deprivation of rest. Study 4 directly tested hypotheses 3, 4, and 5 (that movement and rest desires are states, change with exposure to stimuli and are related to psychosomatic sensations). We hypothesized that a bout of maximal exercise would satiate the desire to move and deprive the body of respite, thereby leading to reductions in the desire to move and increases in the desire to rest. Maximal exercise results in considerable increases in pain and fatigue and large decreases in perceived energy (Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2014a, 2016). Such unpleasant sensations seem likely to result in reductions in desire to move, increases in desire to rest and/or increases in aversions or dread to move (Stults-Kolehmainen et al., 2020a). We hypothesized, in accordance with hypothesis 5, that desires/wants to move and rest will be related to, but distinct from sensations of physical and mental energy and fatigue. This will also help to establish the convergent and discriminate validity of the CRAVE scale (Clark and Watson, 1995, 2019).

## Methods

Study 4 included 21 students ($M_{\text{age}} = 20.5 \pm 1.4$ yrs; 58% female) who identified themselves as 42.9% Caucasian, 19% Asian/Pacific Islander, 19% Hispanic, 14.3% multiple races and 4.8% Arab. The students were mainly undergraduates participating in physical activity classes at The University of Texas at Austin. The study was approved by the University of Texas at Austin's Institutional Review Board and informed consent was obtained from all participants.

Participants were advised to refrain from exercise for 48 h prior to the laboratory testing session. During the testing session, participants completed a maximal, graded treadmill test that was developed for this population of college students. In this protocol, the grade or speed of the exercise was increased every minute for the first 10 min and then speed only was increased every minute until participants reached volitional fatigue. Once this demarcation was reached, speed and grade were reduced to provide the participant with a 5-min cool down walk.

Desires/wants, physical energy, physical fatigue, mental energy and mental fatigue were measured one minute prior to starting the treadmill test, as well as 2 min after completing the test. The CRAVE 13-item version for "Right now" was utilized as found from Studies 1 and 2 (10 items scored, 3 filler items). Physical and mental fatigue and energy were measured pre- and post-exercise using Visual Analogue Scales developed and validated by Herring and O'Connor (2009) and O'Connor (2004). Respondents placed a mark on a standard 10-cm line. Examples of anchors included, "I have no energy" to "Strongest feelings of energy ever felt." Sense of effort was assessed with the Rating of Perceived Exertion (RPE) scale from Borg (1998) with a range of 6–20. Statistical tests were conducted using R (Version 4.0.2; R Foundation for Statistical Computing, Vienna, AT, United States). Paired t-tests were used to compare pre- and post-CRAVE scores. Effect sizes were calculated using Cohen's $d_{av}$ (Cumming, 2013; Lakens, 2013), as well as conditional $R^2$, which is intended to obtain an effect size that considers fixed and random effects in a mixed-effects model (Nakagawa and Schielzeth, 2013). Pearson's correlations were used to assess relationships between all

CRAVE scores, mental fatigue and energy, as well as physical fatigue and energy.

## Results

On average, participants took 13.5 ± 2.0 min to reach volitional fatigue on the treadmill test, reached a maximum heart rate of 194.7 ± 10 bpm and reported a RPE of 18.3 ± 1.0. Desire to move significantly decreased from pre- to post-treadmill test (33.5 ± 8.3 vs. 24.8 ± 8.3, $p < 0.01$, Cohen's $d_{av} = 1.05$, $R^2 = 0.62$), as shown in **Figure 2**. Conversely, desire to rest significantly increased from pre- to post-treadmill test (11.7 ± 12.8 vs. 20.4 ± 8.5, $p < 0.01$, Cohen's $d_{av} = 0.82$, $R^2 = 0.30$). Baseline desire to rest was significantly associated with the change in move ($r = 0.41$, $p < 0.01$) and change in rest ($r = -0.43$, $p < 0.01$). In addition, change in desire to move was inversely associated with change in desire to rest ($r = -0.69$, $p < 0.001$). Pre-exercise move and rest were inversely associated ($r = -0.37$, $p = 0.01$), and the inverse relationship between move and rest scores was stronger post-exercise ($r = -0.64$, $p < 0.001$).

**Figure 3** shows the results of all correlation tests conducted. Change in desire to move had a negative association with change in physical fatigue ($r = -0.50$, $p < 0.001$) and with change in physical energy ($r = 0.33$, $p < 0.01$), but not with mental energy ($r = -0.09$) or mental fatigue ($r = -0.09$). Change in rest had a significant inverse correlation with change in physical energy ($r = -0.62$, $p < 0.001$) and a positive correlation with change in physical fatigue ($r = 0.51$, $p < 0.001$). However, it was not correlated with change in either mental energy or fatigue.

## Discussion

Data from Study 4 demonstrated that desires to move and rest change with a maximal exercise stimulus, thus supporting hypotheses 3 and 4. Desires/wants to move and rest appear to function as psychological states that are sensitive to the provision of an exercise stimulus. In accordance with the WANT model (Stults-Kolehmainen et al., 2020a), a bout of maximal exercise appears to satiate the desire to move and places the body in a state of physiological deprivation for rest. This was demonstrated with a decrease in desire to move and an increase in desire to rest from pre- to post-treadmill exercise. Further, these findings show that perceived physical fatigue has a positive association with the desire to rest, and an inverse association with the desire to move. Additionally, perceived physical energy had a negative association with the desire to rest. Correlations were small to medium in size, providing evidence that the CRAVE captures a unique construct. Overall, these findings provide convergent validity of the scale. They also support the use of the CRAVE Scale as a tool that is sensitive to changes in the desire to move and rest before and after exercise.

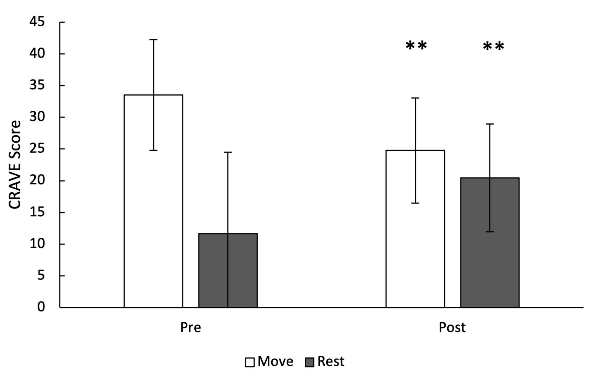


**FIGURE 2 |** Desires/wants to move and rest pre- and post-maximal treadmill exercise test. Move and rest are 5-item sub-scales with scores ranging from 0–50 ** denotes $p < 0.01$.

Several strengths and limitations were identified. A limitation to this study is that the pre-test time period was not monitored for activity, and it is not known whether participants honored the request to refrain from exercise for 48 hours. Therefore, it is unknown if the desire to move was sufficiently built up during this time. Also, the current study did not assess positive and negative affect – other factors that likely relate to desires to move, albeit not strongly (Williams and Evans, 2014). A strength of this investigation was that all participants were pushed to their apparent physiological maximum during treadmill exercise. Everyone followed a controlled protocol with no premature conclusions. However, this was not verified with an analysis of inspired and expired gases (Howley et al., 1995). In a future study, researchers should examine changes in the desire to move and rest when completing an exercise protocol where everyone achieves a set relative intensity for a given time period (e.g., 15 min at 85% of $VO_{2max}$). It would also be useful to examine these changes with a more ecologically valid exercise protocol, in a real-life exercise setting, such as a full resistance training workout, sports game, a 2-mile run, etc. Future studies should also track recovery of desires for a sufficient period after they have been altered (e.g., over 30 min, 2 h or more) (Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2014a).

# STUDY 5

## Introduction

In Study 4, we investigated changes in the desire to move or rest in response to a bout of maximal exercise. In contrast, the purpose of Study 5 was to assess changes in the desires to move or rest in response to sedentary behavior. Study 5 directly tested hypotheses 3 and 4 (the desires will change in a state-like manner with the avoidance of movement), hypothesis 5 (relation to psychosomatic sensations), and indirectly tested hypotheses 1 and 2 (desires for movement exist and are separate from desires to rest). Desires to move and rest should vary by deprivation or satiation of these behaviors (Redden, 2015). Consequently, restricting movement, particularly in a group of individuals more likely to move (i.e., young adults) should result in increased desires to move. Conversely, satiating the need to rest through sedentary behavior should result in fewer of these desires. As the sedentary behavior is prolonged, the desire to move will build up and be felt as a type of tension, perhaps analogous to appetite (Loewenstein, 1996; Rowland, 1998; Ferreira et al., 2006). Based on these premises, we hypothesized that prolonged sitting during a university lecture period would increase the desire to move and

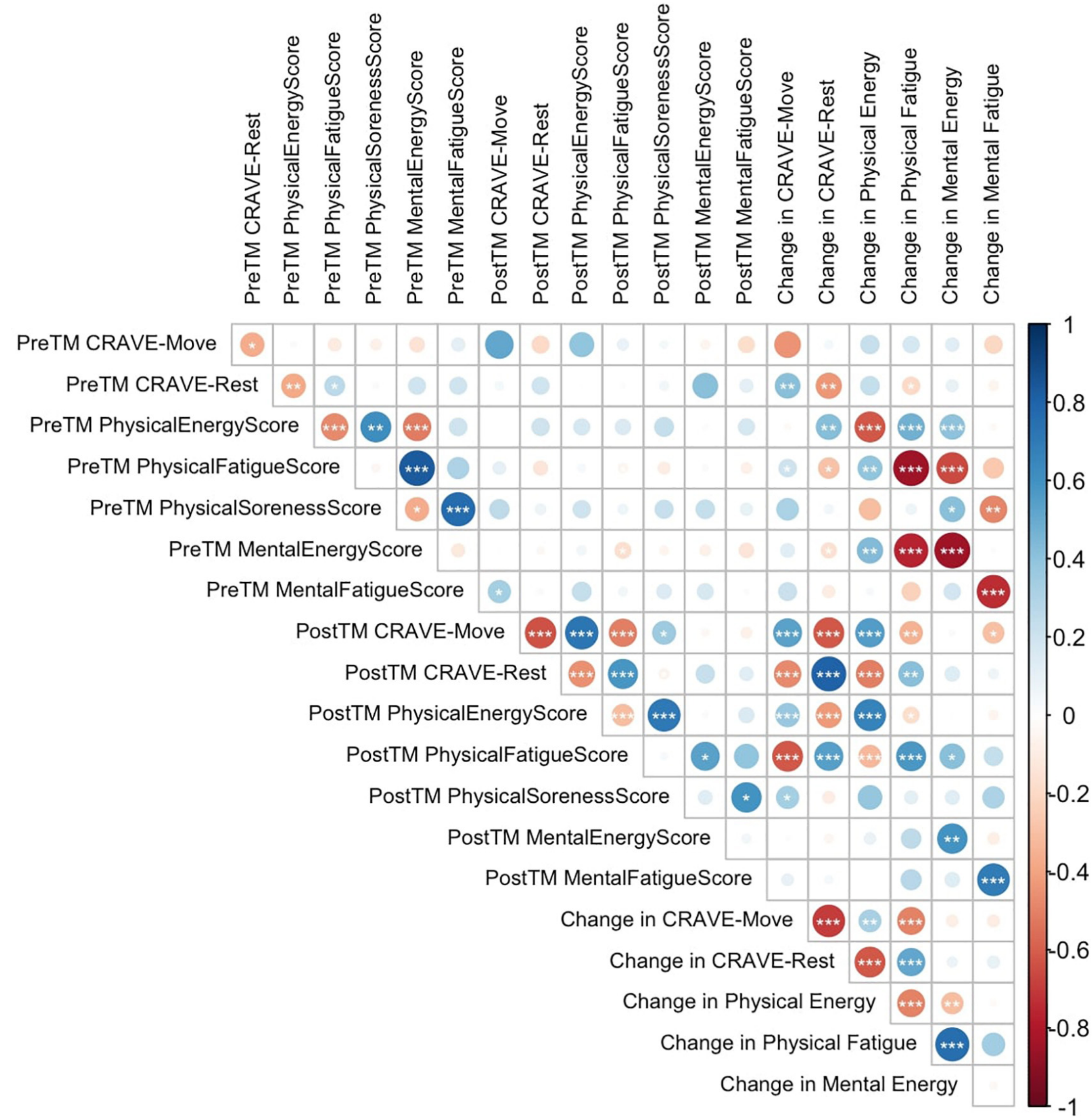


**FIGURE 3 |** Pearson correlation matrix between pre- and post-treadmill test move and rest scores, physical energy, physical fatigue, mental energy and mental fatigue scores, and change in those scores. TM, treadmill. * denotes $p < 0.05$; ** denotes $p < 0.01$; *** denotes $p < 0.001$.

decrease the desire to rest (hypotheses 3 and 4). Convergent and discriminate validation of the CRAVE scale requires examining other instruments that are also psychological states that may overlap but be distinct from desires to move and rest (Clark and Watson, 1995, 2019). It is proposed that desire to move/rest will be related to, but distinct from, perceptions of energy, fatigue, tension, and calmness (in accordance with hypothesis 5). A final aim was to determine the test-retest reliability of the CRAVE scale.

## Methods

The CRAVE Scale and Thayer Activation-Deactivation (AD) Checklist (Thayer, 1986) were administered to 41 students (mean age 22.5 ± 5.1 years; 24.4% female) before, during and at the end of a 50-min lecture. The 13-item version for "Right now" was utilized as found from Studies 1 and 2 (10 items scored and 3 are fillers). In this study, 73.2% of participants identified themselves as Caucasian, 12.2% as Multiple Races, 2.4% as Native American, 2.4% as Hispanic, 2.4% as African American, 2.4% as other and 4.9% did not report ethnicity. Students quietly sat, listened, and took notes while the instructor delivered a PowerPoint presentation. The AD Checklist consists of 20 items answered on a 1–10 Likert Scale and measures perceived energy, tiredness, tension and calmness. This measure was only assessed pre-lecture. Lectures were at either 9AM, 11AM, or 3PM, when one of the current investigators (AD) was scheduled to provide classroom instruction. Statistical tests were conducted using R (Version 4.0.2; R Foundation for Statistical

Computing, Vienna, AT, United States). A linear mixed effects model was used to compare pre-, mid-, and post-lecture CRAVE Scores. Correlations were calculated to evaluate CRAVE and AD Checklist relationships. One-way ANOVA tests were used to assess differences between class times for Move and Rest Scores at the pre-, mid-, and post-lecture conditions. Reliability index was assessed with inter-class correlations, where the reliability of the pre-, mid-, and post-lecture move and rest scores was considered. All individuals signed an informed consent. The study was approved by the Institutional Review Board at Western Illinois University, in accordance with the Declaration of Helsinki.

## Results

It was found that the move scores were significantly higher post-lecture compared to pre-lecture (26.8 ± 10.8 vs. 22.4 ± 11.3, $p < 0.01$) and trended toward a significant difference compared to mid-lecture (23.5 ± 11.3, $p = 0.051$), as shown in **Figure 4**. A main effect of time was found for rest scores [F(2,78) = 3.76), $p < 0.05$], where post-lecture rest scores were significantly different from mid-lecture (18.0 ± 11.9 vs. 21.8 ± 13.4, $p < 0.05$), but not significantly different from pre-lecture scores (21.0 ± 12.2, $p = 0.11$). Inter-class correlations were of moderate strength for the desire to move (*ICC* = 0.68) and the desire to rest (*ICC* = 0.72) (Koo and Li, 2016).

There were no differences in Move or Rest scores based on time of day for any of the pre-, mid-, or post-lecture conditions. As seen in **Figure 5**, pre-lecture move scores were positively associated with mid-lecture move scores ($r = 0.66$, $p < 0.001$), post-lecture move scores ($r = 0.56$, $p < 0.01$), pre-post changes in rest scores ($r = 0.59$, $p < 0.01$) and inversely associated with pre-lecture rest scores ($r = -0.62$, $p < 0.001$), mid-lecture rest scores ($r = -0.52$, $p < 0.01$), post-lecture rest scores ($r = -0.18$, $p < 0.05$). Pre-lecture rest scores were positively associated with mid-lecture rest scores ($r = 0.68$, $p < 0.001$), post-lecture rest scores ($r = 0.70$, $p < 0.001$), and inversely associated with both mid-lecture move scores ($r = 0.52$, $p < 0.001$) and post-lecture move scores ($r = -0.58$, $p < 0.001$). Pre-to-post changes in move scores were negatively associated with pre-to-post changes in rest scores ($r = -0.68$, $p < 0.001$). Pre-lecture move scores had small and inverse associations with pre-lecture tiredness ($r = -0.17$, $p < 0.05$) and total deactivation ($r = -0.20$, $p < 0.05$). Mid-lecture move scores were also inversely associated with pre-lecture tiredness ($r = -0.31$, $p < 0.01$) and total deactivation ($r = -0.35$, $p < 0.05$).

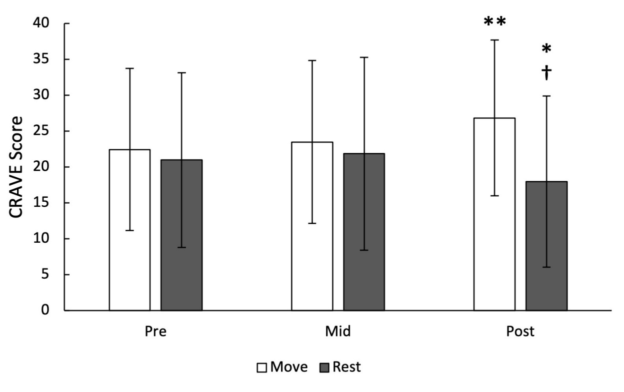


**FIGURE 4 |** Desire to move and rest pre-, mid- and post-lecture. Move and rest are 5-item sub-scales with scores ranging from 0–50. * denotes $p < 0.05$; ** denotes $p < 0.01$; † Denotes that rest had significant difference from mid- to post-lecture, but move had significant difference from pre- to post-lecture.

When the CRAVE was scored with all 13 items (7 for rest, 6 for move), in other words, scoring with the inclusion of the filler items, there were some additional significant findings. There was a significant difference between pre- and post-lecture for rest (33.4 ± 2.8 vs. 28.3 ± 2.8, $p < 0.05$). Further, there was a significant difference between mid- and post-lecture move scores (28.5 ± 2.0 vs. 32.2 ± 2.0, $p < 0.05$). There were also four additional significant correlations with the Activation/Deactivation Checklist: pre-lecture move score was significantly associated with energy ($r = 0.38$, $p < 0.05$) and calmness ($r = -0.47$, $p < 0.01$). Pre-lecture rest was significantly associated with energy ($r = -0.38$, $p < 0.05$) and tiredness ($r = 0.48$, $p < 0.01$).

## Discussion

It was found that the desires to move and rest change throughout the course of a period of sedentary behavior. Specifically, prolonged sitting during a university lecture was associated with an increased desire to move and decreased the desire to rest. This seems to align with literatures that describe movement restriction and prolonged sitting in the classroom and in airplanes as resulting in greater somatic complaints (Zuckerman et al., 1968), discomfort (Bouwens et al., 2018), and inability to attend to instruction (Reardon et al., 2008). Alternatively, forthcoming movement transitions and the anticipation of movement may generate desires to move and allay those for rest. Desires to rest and move, as measured by the 10-item version of the CRAVE, were related to tiredness but not to other psychosomatic sensations. Likewise, Casper has found that urges to move, as retrospectively assessed over two weeks, were unrelated to physical and mental tiredness and energy (Casper, 2020; Casper et al., 2020). Data from Study 5 support the notion that desires are states. Accordingly, the CRAVE demonstrated "moderate" reliability, as might be expected from the beginning of a class to the mid-point and the end. Overall, these findings show that the CRAVE Scale is a tool that is sensitive to changes in the desire to move and rest before and after a relatively short period of sedentary behavior.

This study had several strengths and limitations. A strength of this investigation was that the observation periods were standardized across the sedentary period (pre-, mid-, and post-lecture), and the data was collected at multiple times during the day. However, students did not return to be observed at multiple hours of the day; therefore, within-participant difference at each time of day could not be assessed. Moreover, no data was collected in the evening or at awakening. Consequently, this methodology is limited in the extent to which it can ascertain the influence time of day has on changes in the desire to move or rest. Future research should track individuals multiple times per day, on weekdays and weekends, from the moment of waking until

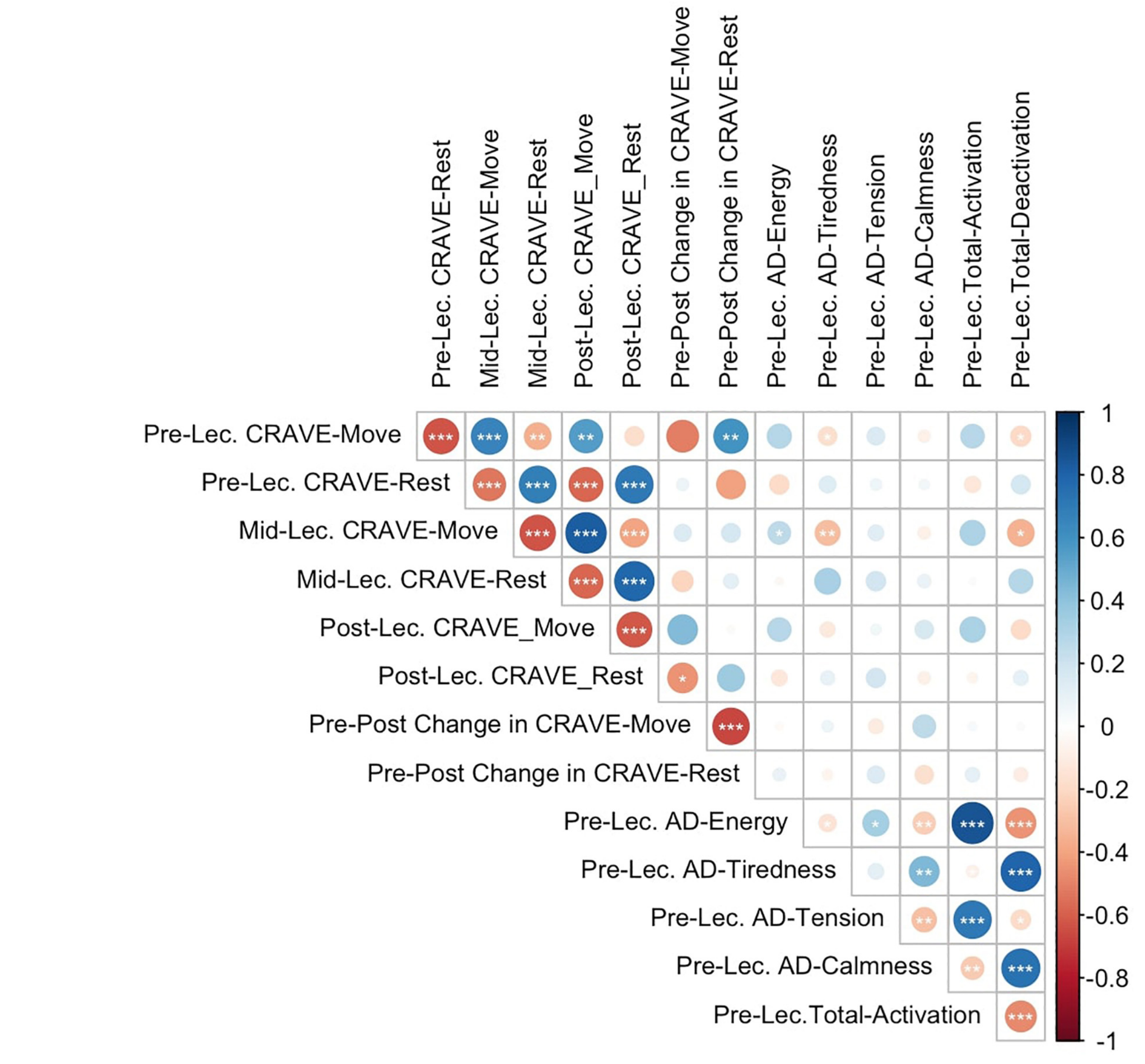


**FIGURE 5 |** Pearson correlation matrix between pre, mid-, and post-lecture move and rest scores, energy, tiredness, tension, calmness, total activation and total deactivation. Lec, lecture; AD, Thayer Activation-Deactivation Checklist. * denotes $p < 0.05$; ** denotes $p < 0.01$; *** denotes $p < 0.001$.

bedtime to understand the natural variation of desires to move and rest throughout a day and across a week or longer. It would be useful to collect these with sensor data and construct models to understand covariates of the effects, such as physical activity, diet, sleep and the environment (Liu et al., 2020).

## GENERAL DISCUSSION

The main objective of the current investigation was to create and validate an instrument to measure affectively charged motivation states (ACMS; e.g., desires, wants, urges and cravings) for movement and rest, which was named the CRAVE. Exploratory structural equation models run in two samples revealed that a two-factor solution for movement (5 items) and rest (5 items) desires/wants produced the best fit. These two factors were inversely correlated at a moderate level, suggesting an overlap but no issues with discriminant validity. Results across studies indicated that desires/wants are transient and typify a motivation state rather than a trait. The CRAVE was sensitive to change when participants partook in a maximal treadmill test as wants/desires for rest greatly increased and desires for movement decreased. On the other hand, changes were much smaller across an hour-long period of sitting and listening. Responses to the scale were more closely correlated when observations were separated by just a few hours, compared to intervals of 6 months or more. Interestingly, desires to move were consistently higher than desires to rest. Overall, these studies found substantial support for the psychometric properties of the CRAVE, including reliability, and they also supported tenets of the WANT model Stults-Kolehmainen et al. (2020a).

The current data indicate that desires for movement and rest likely fall on two different, but related factors. In other words, the desire for movement is not simply *the lack of desire* for rest, or sedentary behavior, which would imply that the two desires are opposite poles on the same dimension (Stults-Kolehmainen et al., 2020a). A two-factor distinction mirrors current thinking about physical activity and sedentarism, as introduced above (Owen et al., 2010; Pettee Gabriel et al., 2012). Furthermore, it may be possible that one has high desire for both rest and movement simultaneously, or low desire for both as well. For instance, in the case of meditation, an individual may experience a lack of desires to both move and rest. Likewise, being high on desire for movement does not necessitate a low level of desire for rest; as in fact, the two may be in conflict. Unfortunately, it was not within the scope of the current studies to specifically test for various patterns of responses, but a more expansive review has been conducted by Stults-Kolehmainen et al. (2020a). From a neurological perspective, regulation of impulses in the brain for energy expenditure and sedentary behavior appears to fall on two distinct corticostriatal pathways, which Beeler and colleagues call "Go" and "No Go" (Beeler et al., 2012). Furthermore, brain systems responsible for sensations of reward and sensations of pain regulate both aversion to movement and/or "craving" for physical activity, and these differ from systems responsible for desire for rest (Bauman et al., 2012). These models are also parsimonious with a vast literature base describing function of the sympathetic and parasympathetic nervous systems (Recordati, 2003). Thus, desires for movement and rest likely operate asymmetrically and are moderately coupled, similarly to the dual system models proposed for energy and fatigue (O'Connor, 2004), activation and deactivation (Thayer, 1987) and positive and negative affect (Watson, 1988).

Desires, by definition, have state-like qualities (Papies and Barsalou, 2015), and this appears to be true for desires for movement and rest. Analysis of NOW and WEEK factors of the CRAVE subscales confirmed that these versions were related, but distinctly different. These data suggest that participants were able to differentiate their urge/desires in the present moment versus their typical desires over a much longer period of time. As a state, one might surmise that movement and rest desires vary in patterns similar to state measures of affect (i.e., arousal, pain, energy and fatigue) (Thayer, 1978; Herring and O'Connor, 2009; Stults-Kolehmainen and Bartholomew, 2012; Stults-Kolehmainen et al., 2016). Indeed, this is what was found. With a maximal treadmill test, desires/wants to move decreased and desires to rest increased, and with an hour-long lecture period, changes were also observed. It is possible that desires/wants for rest and movement may fluctuate diurnally and may further undulate with feedings, sleep, and lifestyle physical activity as interspersed throughout the day (Thayer, 1987). Future research should aim to understand how desires to move and rest vary across the day with arousal, energy, fatigue, distress and other components of affect. It would be useful to determine what other factors affect movement desires, such as environmental cues like lighting (Dunai et al., 2007), music (Levitin et al., 2018; Matthews et al., 2019), social interactions (Graupensperger et al., 2019), et cetera (Stults-Kolehmainen et al., 2013b; Papies and Barsalou, 2015). It can be said with near certainty, however, that desires/wants to move and rest fluctuate across time and capture a motivational state.

On the other hand, one might construe that urge and desires for activity and sedentary behaviors are stable and/or may be highly influenced by intra-individual traits. Substantial individual differences have been noted not only in physical activity, exercise and non-exercise activity thermogenesis (NEAT) (Levine et al., 2005), but also in the acute averse and rewarding effects of physical activity (Bauman et al., 2012; Flack et al., 2020). Such a trait would likely possess a strength that is normally distributed throughout the population and expressed most strongly in young age (Garland et al., 2011). Some children demonstrate more active temperaments, kinetic personalities (i.e., hyperactivity), or a *predilection* for physical activity while others are ostensibly more lethargic (Hay, 1992), traits that may persist into adulthood (Windle and Lerner, 1986; Anderson et al., 2004). In a community sample of adults (Study 3), it was found that motivation states trended down (for move) and up (for rest) over a two-year period. As such, more resources are needed to understand how desires might evolve over an extended period of time (e.g., seasonally, over years) and how they can be intervened upon.

Although addressed later in analyses, perhaps the most important hypothesis concerns the very existence of desires/wants to move and rest. It was hypothesized that study respondents would indicate that they perceived desires/wants for movement and rest. In other words, they would not respond with 0 ("none at all"). This is exactly what was found. On the one hand, one might consider this conclusion to be obvious and a trivial matter. However, there is some debate as to whether humans desire movement to a level that it is noticeable. Rosa et al. (2015) have argued that exercise or physical activity, in themselves, at least from an evolution viewpoint, cannot be primary motivators of behavior. In other words, movement is a by-product, motivated by some other goal, need or extrinsic factor - a means to other ends. Any want of movement would always be overshadowed by desires to rest, be inactive and minimize energy expenditure (Cheval and Boisgontier, 2021). This line of reasoning holds that humankind evolved a thrifty gene to spare energy, and movement is merely a necessity to avoid harm or to obtain food, shelter, and other desired things (Ekkekakis et al., 2005; Williams and Bohlen, 2019). As modern humans rarely need to move to accomplish these primordial objectives, the desire to move would likely be minimal. Moreover, one could point out that exercise is fatiguing, painful and possibly feels punishing, thus not reinforcing (Williams and Bohlen, 2019), some individuals clearly do not enjoy exercise or physical activity (Chinn et al., 2006), humans are possibly "hard-wired" to be sedentary (Cheval et al., 2018, 2020), and a large portion of the population is, indeed, inactive (Cheval and Boisgontier, 2021). All of these phenomena likely developed in response to the human need to avoid a negative energy balance.

The counterarguments indicating the presence of desires/wants to move are equally numerous. First, humans have a strong drive for stimulation (Wilson et al., 2014), and movement may satisfy some of that need. Interestingly, hunter-gather societies engage in frequent cycling of sitting and standing, switching about every 30 min, even on highly inactive days (Lieberman, 2020). Furthermore, as human movement is adaptable and results in greater environmental fitness, it seems likely that it would be wanted at some basic level (Ekkekakis et al., 2005). Even in modern humans, exercise is rewarding for many individuals, similar to food or money (Albelwi et al., 2019). The WANT model predicts that desires/wants for movement might even reach levels of strong urges or cravings (Stults-Kolehmainen et al., 2020a). Such cravings are known to exist, in cases of psychiatric illness (Iqbal et al., 2007), neuromuscular disorders (Garcia-Borreguero et al., 2011; Zhu et al., 2019), or exercise addiction/dependence, in particular (Hausenblas and Downs, 2002). Those who "crave activity" likely have rewards systems that activate in response to physical activity and exercise (de Geus and de Moor, 2011; Bauman et al., 2012). Neurological and genetic underpinnings of desires to move have been identified (see Stults-Kolehmainen for a short discussion) (de Geus and de Moor, 2011; Garland et al., 2011; Stults-Kolehmainen et al., 2020b). Such pathology is relatively contained to special populations or in response to specific stimuli (Levitin et al., 2018; Matthews et al., 2019); however, begging the question of whether they are relevant for the general population. This study is one of the first to concretely demonstrate that humans clearly perceive themselves as having desires to move and these are separable from desires to rest.

To understand these processes, future studies should aim to assess movement and rest desires in a variety of populations. The CRAVE was developed in a sample that was ethnically diverse (e.g., in Study 2, participants were 52.5% non-Caucasian and in Study 4, 57.1% non-Caucasian), but the scale should be validated in a variety of different countries, cultures and languages. Furthermore, except for Study 3, the current studies were mostly limited to young adults completing undergraduate education. Since the mid-1800s, it has been submitted that while desire is especially strong for the young and those well-trained, it declines with age and deconditioning (Bain, 1855; Baldwin, 1891, 1894; Ekkekakis, 2013a). One might expect that training status, fitness and habituation to physical activity would also have an impact on desires for movement. For instance, sedentary and low-active individuals are more likely to experience displeasure during exercise even when it is of low intensity (Williams et al., 2008). Furthermore, regular exercisers experience greater improvements in mood than non-exercisers (Hoffman and Hoffman, 2008), and highly active individuals report that enjoyment is the primary motive of exercise (Stults-Kolehmainen et al., 2013a). Indeed, in the current analysis stage-of-change for exercise predicted wants/desires for movement. However, it would be useful to determine whether those with higher movement desires actually have more energy expenditure (EE) from exercise or non-exercise sources (e.g., occupational activity, active transit, spontaneous physical activity [SPA]) (Levine et al., 2005; Casper, 2020) and whether these change over time with chronic training. Movement desires and urges, or what has been termed "appetence," is magnified with exercise addiction, anorexia nervosa, and possibly mania (Ferreira et al., 2006; Cheniaux et al., 2014). Thus, it is likely, but still speculative, that desires vary over time and across populations, situations, and conditions.

Conversely, the desire to move and rest may decrease with a variety of conditions. Movement and rest wants/desires likely are altered by conditions like acute and chronic illness (Skinner et al., 2009), depression (psychomotor retardation) (Buyukdura et al., 2011), and distress (psychomotor agitation) (Kessler et al., 2002), which may modify incentive salience for movement (Robinson and Berridge, 1993; Berridge and Robinson, 1998; Robbins and Everitt, 2007). Some neuromuscular disorders, like Parkinson's, are characterized by *apathy* for motor tasks - a near total lack of desire to move (Zhu et al., 2019). As early as 1896, Stedman noted that with nervous and mental disease "the natural conscious *craving* for exercise is lost" (Stedman, 1896). Overtraining and exercise burnout have depression-like symptoms and would likely result in altered wants/desires. If such conditions are strong enough, they may even result in dread or aversion for movement as highlighted by the Affect and Health Behavior Framework (AHBF) (Williams and Evans, 2014; Williams et al., 2019) and further conceptualized by Stults-Kolehmainen et al. (2020a). Some have argued that the concept of dread for movement is more important as a target for public health initiatives than wants/desires (Williams and Bohlen, 2019). Unfortunately, the current studies were not designed to address the concept of movement avoidance, aversion or dread, and many unknowns exist for these concepts, such as their basis in the brain and neural circuitry (for a review, see Barke et al., 2012). How desires/wants and dread interact should be actively investigated.

Future research should also address how these desires motivate to spur behavior (Williams and Evans, 2014; Williams et al., 2019). Desires vary in magnitude, focal attention, and their effect on working memory, which results in differential implications for a wide swath of behaviors (Robinson and Berridge, 1993). Intense desires, manifested as psychophysiological cravings and urges, strongly predict future behavior, such as overeating, binging on alcohol, overconsumption of caffeine, excessive engagement in sexual activity, smoking of cigarettes and other behaviors (Sinha, 2001; Tiggemann and Kemps, 2005; Kemps and Tiggemann, 2009). Casper and colleagues documented that the increased urge to move in severely underweight adolescent anorexia nervosa patients was positively associated with exercise volume and intensity over a two-week period (Casper, 2020; Casper et al., 2020). As demonstrated by the Dynamical Model of Desire (Hofmann and Van Dillen, 2012), wants that emerge into focal attention in working memory often instigate active pursuit of that desire. Weak, transient desires, on the other hand, may go unnoticed, overshadowed by other desires, and may not result in any changes in behavior (Loewenstein, 1996; Papies and Barsalou, 2015). However, desires not in focal attention may still motivate behaviors with impelling force through an automatic route of influence. This may be the case for movement, the desire of which is often of a weaker nature, has a smaller demand for attention and exerts less influence on working memory than food or sleep. Nevertheless, it's possible that desires for energy expenditure may play a key role in influencing movement behaviors and may help to explain compensatory responses to exercise, such as a substantial decrease in activity right after vigorous muscular exertion (Ferreira et al., 2006). The CRAVE scale may be utilized to investigate this array of complex processes.

## CONCLUSION

While theoretical models for cravings/desires for exercise have emerged, the systematic investigation of these constructs is still in its infancy, having been impeded by a lack of instrumentation. We developed a novel measurement tool, the CRAVE, to gauge the want/desire of movement and rest both "right now" and "in the past week". These were tested in 5 samples: 2 large groups of undergraduate students tested cross-sectionally, 2 groups tested multiple times per session and 1 group of community-dwelling adults assessed over a 2-year time period. ESEM determined that this instrument has good psychometric properties, distinguishing between desires for movement and rest. It is also sensitive to the state-like nature of the construct. Small changes were observed over a lecture period and large changes were observed with a bout of maximal exercise. Desires to move and rest were associated with perceptions of physical energy, fatigue and tiredness. Consequently, the CRAVE has good construct validity. Analyses herein also served to test facets of the WANT model (Stults-Kolehmainen et al., 2020a), which were all supported. Interestingly, movement desires were consistently higher than those for rest across all studies. Such a tool may be a valuable resource for researchers interested in psychological wants/desires and how they relate to changes in facets of physical activity and sedentary behaviors in the present moment. It may be particularly useful for those studying exercise addiction/dependence, aging, responses to music (i.e., "groove"), neuromuscular disorders, rehabilitation, and interventions to promote physical activity. Future work should determine how wants/desires vary by environmental and within and between person factors and whether promoting desires for movement and/or resisting desires for rest results in greater movement behavior.

## DATA AVAILABILITY STATEMENT

Datasets from Studies 1 and 2 presented in this study can be found in online repositories. The names of the depository/repositories and accession number(s) can be found below: https://figshare.com/authors/Matthew_Stults_kolehmainen/794794.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Yale School of Medicine Human Investigation Committee, The University of Texas at Austin Institutional Review Board, Northern Illinois University Institutional Review Board, and Western Illinois University Institutional Review Board. The participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

MS-K and MB are co-first authors and primary contributors to the writing of the manuscript. RS is senior author. MS-K, RS, and JB developed the initial concept. MS-K, RS, JB, TG, AD, and PS created the study designs, developed study procedures, and coordinated and collected the data. NF conducted the exploratory structural equation models in consultation with AF and TG. NF, MB, and PM conducted linear mixed and regression models. MS-K, MB, TG, PM, LB, SW, and GA conducted all other supporting data analyses. NF, TG, RS, JB, AF, PM, GA, JC, PS, AD, LB, and SW also contributed to the writing of the manuscript (in order by level of contribution). All authors contributed substantially to the article and approved the submitted version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.568286/full#supplementary-material

**Supplementary Data Sheet 1 |** The scale development.

**Supplementary Data Sheet 2 |** The actual scale.

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# Athlete Experiences of Shame and Guilt: Initial Psychometric Properties of the Athletic Perceptions of Performance Scale Within Junior Elite Cricketers

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Guilt and shame are self-conscious emotions with implications for mental health, social and occupational functioning, and the effectiveness of sports practice. To date, the assessment and role of athlete-specific guilt and shame has been under-researched. Reporting data from 174 junior elite cricketers (M = 17.34 years; females $n = 85$), the present study utilized exploratory factor analysis in validating the Athletic Perceptions of Performance Scale (APPS), assessing three distinct and statistically reliable factors: athletic shame-proneness, guilt-proneness, and no-concern. Conditional process analysis indicated that APPS shame-proneness mediated the relationship between general and athlete-specific distress ($p < 0.01$), with this pathway non-contingent on sex or past 12-month help-seeking for mental health concerns ($p$'s $> 0.05$). While APPS domains of guilt-proneness and no-concern were not significant mediators, they exhibited correlations in the expected direction with indices of psychological distress and well-being. The APPS may assist coaches and support staff identify players who may benefit from targeted interventions to reduce the likelihood of experiencing shame-prone states.

**Keywords: guilt, shame, self-conscious emotions, distress, mental health, help-seeking**

## INTRODUCTION

The ways in which athletes appraise their performance and the associated self-attributions can influence perceptions of athletic success or achievement, and the perceived need for reparative action where performance is viewed as suboptimal (e.g., below their known ability level). While some athletes may internalize a critical or harsh narrative to motivate enhanced training or preparation, this approach is typically counterproductive, with the potential for unfavorable comparisons relative to peers, past performance, or goal attainment (Powers et al., 2009) and the possibility of a loss of confidence after perceived failure (Stoeber et al., 2008). If the central goal of athletic coaching is to use the coach-athlete relationship to facilitate positive changes in athlete competence, confidence, connection and character (Côté and Gilbert, 2009; Vella et al., 2010), to effectively execute these responsibilities, coaches need access to a depth of information beyond performance and achievement metrics. Assessing, and where necessary ameliorating problematic athletic self-perception — especially in relation to negative self-conscious emotions (e.g., shame and guilt) — is likely to be an important aspect of facilitating domains of competence, confidence, connection and character that contribute to athlete well-being and performance. While maturation processes may support youth athletes developing insight into, and self-management practices for experiences of problematic self-conscious emotions in the sporting context, suitably supportive, and nurturing coaching environments may serve to bolster and enhance innate coping, and fast-track adaptive coping responses in relation to shame and guilt.

Shame and guilt are negative affective experiences that tend to occur following a performance-related failure, or a behavioral transgression, that is perceived as inappropriate, morally wrong, or below internally (or externally) prescribed standards (Tangney, 1991). Though shame and guilt are commonly experienced emotions, they are often (mistakenly) referred to interchangeably. Theorists distinguish these affective states based on the focal point of one's negative evaluation (Lewis, 1971; Tangney et al., 1996). Specifically, when shamed, the *self* becomes a focal point of negative scrutiny and the event that elicits the shame response is often internalized and attributed to stable character flaws (e.g., "*I* failed and therefore *I* am incompetent"; Lutwak et al., 1998; Tangney and Dearing, 2002). Conversely, with feelings of guilt the focus of the negative evaluation is squarely on the discrete regrettable behavior or event, rather than the self (e.g., "What I *did* was wrong"; Tangney et al., 1996). Guilt is also an empathy triggering other-oriented emotional process, in that the individual is acutely aware how their behavior adversely impacts others (e.g., "*I've let my team down*"; Treeby et al., 2016).

Guilt and shame are associated with different motivational and behavioral outcomes. When shamed, the self is interpreted as irreparably flawed and that little can be done to rectify it (Kaufman, 1989). In this sense, the motivational and behavioral outcomes associated with shame tend to be maladaptive and can include avoidance, withdrawal, and disengagement (Tangney, 1991). Alternatively, as experiences of guilt tend to be distinct from an individual's self-concept, the behavioral and motivational outcomes are typically adaptive, as they promote a reparative response (e.g., wanting to cease the problematic behavior or fix the wrongdoing). In comparison to guilt, shame is a much more aversive and disabling experience implicated in a larger range of negative psychological outcomes including motivation and goal striving (Weiner, 1985, 1986; Tangney and Fischer, 1995). Shame-proneness has also been linked with maladaptive perfectionism, depression, distress, anxiety, and substance use as a means of coping with negative emotions (Derogatis et al., 1973; Cook, 1996; Thompson et al., 2003; Treeby and Bruno, 2012).

At present, there is limited research into the experiences of athlete shame and guilt, and there are no sports-specific screening tools for athletic shame and guilt. Research from alternative achievement-based settings (e.g., university) has demonstrated that highly shame-prone individuals that experienced a perceived performance failure were less likely to put effort into similar subsequent tasks (Thompson et al., 2003). Therefore, it may follow that if an athlete experiences shame due to a suboptimal performance (in competition or in training), this athlete may feel less inclined to train harder through increased practice effort, may fail to remain engaged in similar achievement related tasks (e.g., a competitive match), and fail to set task-related goals (e.g., increasing training load). As a direct result of task-related disengagement and a lack of goal-striving behavior, there may also be a reduction in task-related performance (e.g., Thompson et al., 2003). Shame-proneness in particular has been associated with lower mental toughness among athletes, although self-forgiveness was found to mediate this relationship — hence, being mentally tough may actually signify the tendency and/or ability to be more forgiving of one's athletic shortcomings (Cowden et al., 2018). This finding is supported by the growing evidence base of self-compassion focussed interventions among athletes (Mosewich et al., 2019; Wilson et al., 2019), given this approach is known to reduce shame-proneness and associated mental health symptoms (Gilbert and Procter, 2006; Johnson and O'Brien, 2013).

Though research regarding athlete shame and guilt is in its infancy, the implications on future achievement motivation, mental health and well-being, and potential dysfunctional self-protective behaviors is made clear in the broader literature (Tangney and Dearing, 2002; Thompson et al., 2003; Hofseth et al., 2015). As elite sports research is moving toward holistic understanding of athlete psychological and physical health, well-being and performance (Purcell et al., 2019), exploring the degree and impact of shame and guilt in athletes is paramount to informing this global picture. To best understand these concepts, a primary need for validated and athlete-specific measurement tools exists. Extant scales that measure guilt and shame typically use a trait-based approach measured using scenario based items where the respondent is asked how they would react in a given transgressional situation (e.g., the Test of Self-Conscious Affect (TOSCA); Tangney et al., 2000). While widely validated in the general population, these hypothetical situations (e.g., social or moral transgressions) are less directly relevant to the athletic and sporting achievement settings. As argued by Mills (2005), there is a need for domain and context-specific measures of self-conscious emotions. Similarly, existing achievement-based scales, for example, the Achievement Guilt and Shame Scale (AGSS; Thompson et al., 2008) still utilize hypothetical scenarios that will not necessarily reflect experiences of perceived sporting failure.

Given the preliminary nature of sporting guilt and shame literature, and the necessity for domain specific measurement tools, the purpose of this study was to develop and undertake initial psychometric validation of a domain-specific measure of athlete guilt and shame. Identification of sport-specific self-conscious emotions, and their mental health and well-being correlates, may support enhanced targeted early intervention programs in the future. In a sample of elite junior cricket players, we expected exploratory factor analysis to support the existence of distinct putative athlete guilt- and shame-proneness factors, correlating negatively with psychological well-being and positively with general and athlete-specific psychological distress, with higher observed guilt- and shame-proneness female athletes as per existing literature (Else-Quest et al., 2012). Further, athlete shame-proneness in particular was expected to account for additional variance (via mediation analysis) in the relationship between general psychological distress predicting to athlete-specific distress.

# METHODS

## Participants

Australian junior cricket players attending either the male U19 National Championships or the female U18 National Championships were invited to participate. Survey data were provided by 174 players (males $n = 89$, females $n = 85$), with a mean age of 17.34 years ($SD = 1.00$).

## Measures

### Demographic Data

Non-identifying demographic information was collected.

### Athlete Psychological Strain Questionnaire (APSQ)

The APSQ is a brief 10-item screening tool for athlete mental health, which has been shown to have acceptable validity in male ($\alpha = 0.87$) and female ($\alpha = 0.84$) elite athletes (Rice et al., 2019, 2020a). The APSQ includes three subscales assessing self-regulation (e.g., "*I was irritable, angry, or aggressive*"), performance concerns (e.g., "*I found training more stressful*"), and external coping (e.g., "*I needed alcohol or other substances to relax*") in addition to a scale total score. Responses are measured on a five-point Likert scale from *1 = none of the time* to 5 = *all of the time*.

### Kessler Psychological Distress Scale (K10)

The K10 is a 10-item screening tool to assess psychological distress, such as nervousness, fatigue, hopelessness, and depression (Kessler et al., 2003). This tool has been widely validated in a range of populations (Donker et al., 2009; Cornelius et al., 2013; Bougie et al., 2016) including elite athletes (males $\alpha = 0.86$, females $\alpha = 0.80$; Rice et al., 2020a). The scale relates to the previous 4 weeks, and responses are measured on a five-point Likert scale where *1 = none of the time* and 5 = *all of the time*.

### Warwick-Edinburgh Mental Well-Being Scale (WEMWBS)

The WEMWBS is a 14-item scale assessing positive aspects of mental health as a single factor, such as feeling useful, relaxed, and optimistic (Stewart-Brown et al., 2009). Responses are measured on a five-point Likert scale where *1 = none of the time*, and *5 = all of the time*. The scale has also been validated with elite athletes (males $\alpha = 0.94$, females $\alpha = 0.93$; Rice et al., 2020a).

## Scale Development – The Athletic Perceptions of Performance Scale

The Athletic Perceptions of Performance Scale (APPS) was purposively designed to be a brief measurement tool to fill an existing gap in the assessment of athlete-specific self-conscious emotions relative to performance, namely, athletic shame- and guilt-proneness, and no performance concerns, assessed over the past 4 weeks. Following review of the theoretical literature related to the role of self-conscious emotions in achievement-related settings authors MT, SMR, LO, and RP collaboratively developed an initial item set assessing domains of athletic shame and guilt-proneness. The initial item pool was subsequently shared with researchers and practitioners based in the elite setting, who provided expert feedback on wording, clarity and item construction. Following this, a series of item iterations were undertaken until an item pool of 12-items was finalized, which notionally comprised three domains (each with four items), assessing (i) athletic guilt-proneness, with items focusing on the need for reparative performance-based actions (e.g., *"I felt a need to train harder for future matches/contests"*), (ii) shame-proneness, with items focussing on a perceived defective athletic self-identity (e.g., *"I felt useless as a player/athlete"*), and (iii) no-concern, with items focussing on no perceived performance issues (e.g., "*I had no performance issues to worry about*"). The no-concern items were developed to identify those athletes who perceived that they were performing well and were satisfied with their efforts. These items were included to ensure that the scale was relevant to all athletes, irrespective as to how positively or negatively they appraise their performance. Respondents completed the APPS after reading the following introduction "*These questions concern how you have felt following your overall performance over the past 30 days. Please select the answer that best represents your experience where 1 (Strongly disagree) to 5 (Strongly Agree).*"

## Procedure

High performance managers notified staff (e.g., coaches, team managers), players, and their parents/guardians in the months prior to the age group National Championships of the survey. Parents/guardians were encouraged to discuss participation with their child prior to them attending the Championships, however participants aged over 16 years were able to consent without parent/guardian approval. At the Championships, a member of the research team presented to each team and invited players to complete the online survey after reading the participant information statement. Players were advised that participation was voluntary and that their decision to participate or individual data would not be identifiable. A psychologist was present at the time of survey completion and throughout the Championships, and details of additional external support (either online and phone) were also provided. The survey was administered via a secure online platform and participants completed the survey on their own mobile device. The average time for survey completion was under 10 min (mean = 9 min, 47 s). Ethics approval was granted by the La Trobe University Human Research Ethics Committee (HEC19480).

## Data Analysis

Descriptive statistics were calculated for all demographic variables to characterize the sample. Between-groups analyses ($t$-tests, $\chi^2$) tested for sex differences. Scale internal consistency values were evaluated using Cronbach's coefficient. In order to identify the number of factors to retain for the APPS, parallel analysis was undertaken using the SPSS macro rawpar.sps (O'Connor, 2000). Parallel analysis is one of the most accurate factor retention methods, providing more reliable factor solutions compared to traditional methods of evaluating scree plots and Eigenvalues >1 (Hayton et al., 2004). Following parallel analysis, principal axis factoring was undertaken, reporting the Kaiser-Meyer-Olkin (KMO) Test for Sampling Adequacy (where KMO $\geq$ 0.70 = good; Hair et al., 2006) and Bartlett's test of sphericity. Direct oblimin rotation was used to enable identified factors to correlate. Per scale development guidelines (Stevens, 1992), any scale items with factor loadings below 0.40 were deleted, as were any items cross-loading >0.32 (DeVellis, 2016). Analyses were re-run following deletion of any items and the final rotated pattern matrix was inspected to guide factor identification and interpretation. Divergent validity was examined by non-parametric (Spearman's) correlations between APPS domains and the WEMWBS (negative associations expected between the APPS guilt- and shame-proneness domains and WEBWBS total score). Convergent validity was assessed by Spearman correlations (reported separately by gender) between APPS domains and APSQ and K10 (positive correlations expected between the APPS guilt- and shame-proneness domains and the APSQ and K10). The APPS no concern domain was expected to be unrelated to the well-being indices (e.g., no statistically significant correlations observed with the APSQ, K10, or WEMWBS). Mediation analysis was undertaken using the PROCESS macro (Hayes, 2017) to determine the role of WEMWBS and APPS domain scores in moderating the K10 – APSQ relationship. A secondary conditional process analysis was undertaken to determine whether observed mediation effects were contingent on sex or past 12-month mental health help-seeking. Separate parallel bootstrapped models were evaluated (normal distribution not required), using 99% CIs and 10,000 bootstrap resamples using PROCESS models 4 and 16 (see Hayes, 2017). In these models, K10 scores ($x$) predicted to APSQ scores ($y$), evaluating APPS domains as parallel mediators ($m$), and moderators participant sex ($w$) and past 12-month help seeking ($z$). Analysis of APPS quartile distribution explored corresponding categories of psychological distress. All analyses were undertaken in SPSS 26.0.

## RESULTS

The response rate for the eligible population participating at the Championships was 62% for males (89/143), and 77% for females (85/111). Male participants ($M$ = 17.93 years, $SD$ = 0.84 years) were significantly older than female participants ($M$ = 16.73 years, $SD$ = 0.75 years), $p < 0.001$. See **Table 1** for participant demographics.

Parallel analysis was undertaken with the APPS item pool, yielding three underlying factors within the dataset. The factorability of the data was "good" (KMO = 0.761) and Bartlett's test of sphericity was significant ($p < 0.001$). Principal axis factoring with direct oblimin rotation was undertaken, with a specified three factor solution. The three factors accounted for 53.29% of scale variance, and were consistent with the theoretically aligned constructs of shame-proneness (eigenvalue 3.98; 30.30% of variance), guilt-proneness (eigenvalue 2.01; 12.84% of variance), and no-concern (eigenvalue 1.62; 10.16% of variance). All items reported factor loadings >0.40 with the expectation of a single shame-proneness item "*I found it hard to face my teammates or coach.*" Due to the low loading, this item was omitted. The analysis was re-run (KMO = 0.754, Bartlett's test $p < 0.001$), with the three factors accounting for 56.84% of scale variance, consistent with the initial analysis of shame-proneness (three items; eigenvalue 3.86; 32.07% of variance), guilt-proneness (four items; eigenvalue 1.98; 13.73% of variance), and no-concern (four items; eigenvalue 1.64; 11.05% of variance). There were no cross-loading items >0.32. The rotated factor solution is presented in **Table 2**.

**TABLE 1** | Participant demographics.

| | Male ($n$ = 89) | Female ($n$ = 85) |
|---|---|---|
| **Cultural and ethnic background** | | |
| Australian | 85 | 78 |
| Indigenous Australian or Torres Strait Islander | <5 | 7 |
| New Zealander | <5 | <5 |
| African | <5 | <5 |
| Asian | <5 | 5 |
| Indian | 7 | <5 |
| European | <5 | <5 |
| **Studying** | | |
| Secondary (high school) | 30 | 64 |
| Tertiary (university) | 20 | 17 |
| Certificate or diploma | <5 | - |
| Trade or apprenticeship | 10 | - |
| No | 27 | <5 |
| **Involvement with cricket in last month** | | |
| Regularly playing/training | 87 | 77 |
| Irregularly playing/training | - | <5 |
| Restricted playing/training due to injury/illness | <5 | 6 |
| Restricted playing/training due to other commitments | - | <5 |
| **History of psychological treatment** | | |
| Yes, in the past 12 months | 14 | 10 |
| Yes, not in the past 12 months | 2 | 5 |
| No | 73 | 70 |

Internal consistency values for the three APSS domains were all satisfactory (APPS Shame-proneness α = 0.94; APPS Guilt-proneness α = 0.71; APPS No-concern α = 0.79), as were the Cronbach coefficients for the K10 (α = 0.89), WEMWBS (α = 0.90), and APSQ with the exception of the external coping subscale, which reported marginal reliability in the present sample (Self-regulation α = 0.77; Performance concerns α = 0.77; External coping α = 0.55; APSQ total score α = 0.85).

APPS subscale means and SDs were evaluated by sex (see **Table 3**). Small effects for participant sex were observed for the APPS Shame-proneness and APPS Guilt-proneness domains, in addition to the K10 and WEMWBS, however only the effect

**TABLE 2 |** APPS descriptive statistics and factor loadings.

| APPS item | *M (SD)* | Response frequency % (*n*) | | | | | Factor loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 "*Strongly disagree*" | 2 | 3 | 4 | 5 "*Strongly agree*" | Shame-proneness | Guilt-proneness | No-concern |
| *I felt useless as a player* | 2.40 (1.00) | 18.1 (31) | 41.5 (71) | 24.6 (42) | 14.0 (24) | 1.8 (3) | **0.932** | −0.046 | 0.037 |
| *I felt worthless and not good enough as a player* | 2.45 (1.01) | 17.0 (29) | 38.6 (66) | 28.7 (49) | 12.9 (22) | 2.9 (5) | **0.895** | −0.047 | −0.007 |
| *I felt like I'm a poor player* | 2.48 (0.91) | 11.2 (19) | 45.3 (77) | 29.4 (50) | 12.4 (21) | 1.8 (3) | **0.880** | −0.060 | −0.024 |
| *I felt a need to work harder for my team* | 3.55 (0.96) | 1.8 (3) | 14.1 (24) | 24.7 (42) | 45.9 (78) | 13.5 (23) | −0.012 | **−0.692** | 0.077 |
| *I felt a need to train harder for future matches/contests* | 3.63 (0.97) | 1.2 (2) | 14.0 (24) | 22.8 (39) | 44.4 (76) | 17.5 (30) | 0.126 | **−0.630** | −0.119 |
| *I felt a need to remove distractions, so I could focus* | 3.16 (0.92) | 2.4 (4) | 23.5 (40) | 33.5 (57) | 36.5 (62) | 4.1 (7) | 0.007 | **−0.568** | 0.070 |
| *I realized I need to avoid repeating mistakes* | 3.54 (0.91) | 2.9 (5) | 9.4 (16) | 29.2 (50) | 48.0 (82) | 10.5 (18) | 0.040 | **−0.491** | −0.182 |
| *I saw no problems with my performance* | 2.32 (0.89) | 17.1 (29) | 44.7 (76) | 28.8 (49) | 8.2 (14) | 1.2 (2) | 0.155 | 0.179 | **0.796** |
| *I felt that I performed my best* | 2.98 (0.93) | 5.3 (9) | 24.7 (42) | 39.4 (67) | 27.6 (47) | 2.9 (5) | −0.164 | −0.140 | **0.719** |
| *I had no performance issues to worry about* | 2.19 (0.82) | 18.3 (31) | 50.9 (86) | 24.9 (42) | 5.3 (9) | 0.6 (1) | 0.063 | 0.097 | **0.654** |
| *I felt that I performed well* | 3.18 (0.85) | 2.9 (5) | 17.1 (29) | 41.8 (71) | 35.3 (60) | 2.9 (5) | −0.246 | −0.157 | **0.596** |

*Bolded text indicates grouping of each factor.*

for APPS Shame-proneness survived correction for multiple comparisons ($p < 0.01$). Female respondents reported higher scores relative to males, with the exception of the WEMWBS where males scored higher.

Domain associations (Spearman correlations) are reported in **Table 4**, with associations ranging from weak to strong, with negative correlations observed for variable pairings with the APPS No Concern domain, and the WEMWBS. Bonferroni adjusted $r$ to $z$ transformations indicated that correlations did not significantly differ by sex.

Partial correlations were calculated between APPS Shame-proneness and APPS Guilt-proneness with the APSQ, K10, and WEMWBS. As construct associations reported in **Table 4** did not differ, analyses were not sex disaggregated. **Table 5** shows the previously significant correlation between guilt proneness and K10 ($r_s = 0.18$, $p = 0.014$) scores was no longer significant ($r_s = 0.13$, $p = 0.106$), indicating no relationship between APPS Guilt-proneness and psychological distress when controlling for APPS Shame-proneness perceptions of performance.

Mediation analysis inspecting non-overlapping 99% CIs indicated that APPS Shame-proneness ($\beta = 0.099$, SE $= 0.033$, 99% CI 0.023–0.192) significantly mediated the relationship between K10 predicting to APSQ scores (total effect predicting to APSQ: $F_{(1,166)} = 276.77$, $p < 0.001$, $R^2 = 0.625$). Neither APPS Guilt-proneness ($\beta = 0.017$, SE $= 0.012$, 99% CI −0.004 to 0.058), APPS No-concern ($\beta = 0.005$, SE $= 0.014$, 99% CI −0.040 to 0.043), or WEMWBS scores ($\beta = -0.010$, SE $= 0.032$, 99% CI −0.097 to 0.074) were significant mediators. Conditional process analysis indicted the APPS Shame-proneness mediation effect was not contingent on gender ($\beta = -0.040$, SE $= 0.057$, 99% CI −0.115 to 0.181), or past 12-month mental health help seeking ($\beta = -0.017$, SE $= 0.324$, 99% CI −0.255 to 0.247). In summary, mediation modeling indicated the effect of K10 on APSQ scores occurred via APPS Shame-proneness, and that this effect was not contingent on gender or recent mental health help-seeking status.

Quartiles for the APPS Shame-proneness scale were examined (see **Table 6**). Players in the fourth quartile (APPS Shame-proneness ≥9) were on average in the "Very high" range for the APSQ, and "High" range for the K10, indicative of the need for coaching and/or mental health intervention. Quartile group comparisons for the APSQ Shame-proneness scale with adjusted *post-hoc* analysis (Scheffe) indicated that each APPS quartile group differed from the others (all quartile comparison $p$'s $< 0.001$), with a large effect size $F_{(3,166)} = 362.79$, $p < 0.001$, partial ?$^2 = 0.855$. For the K10, adjusted *post-hoc* analysis indicated that three of the six quartile group comparisons differed from the others (quartiles 1 and 3 $p = 0.025$; quartiles 1 and 4 $p < 0.001$; quartiles 2 and 4 $p = 0.003$), with a large effect size $F_{(3,166)} = 11.92$, $p < 0.001$, partial $\eta^2 = 0.177$.

## DISCUSSION

As hypothesized, distinct factors were validated for the APPS Shame- and Guilt-proneness subscales, in addition to a distinct no-concern factor, which was negatively associated with both. The higher observed ratings of shame- and guilt-proneness among female players are consistent with findings observed in the general community (Else-Quest et al., 2012). While distinct and statistically unrelated to each other (e.g., non-significant Spearman's correlations) the APPS Shame- and Guilt-Proneness subscales both demonstrated moderate positive associations with general psychological distress and athlete-specific distress (as assessed by the K10 and APSQ respectfully) and were inversely related to psychological well-being. Given those in the uppermost quartile of the APPS Shame-proneness subscale were also, on average, classified in the high distress range on other measures, the shame-proneness domain may have particular utility in identifying players that may benefit from coaching, clinical and/or performance psychology intervention.

As indicated, both APPS Shame- and Guilt-proneness were positively associated with concerns regarding one's performance and issues relating to selection pressures, concerns regarding injury, and training related stress. However, when controlling for guilt-proneness, only APPS shame-proneness was positively

**TABLE 3 |** APPS means and SDs by sex.

| | Total | Male | Female | Inferential | Effect size |
|---|---|---|---|---|---|
| | *M (SD)* | *M (SD)* | *M (SD)* | *t, p* | Cohen's *d* |
| APPS Shame-proneness | 7.36 (2.75) | 6.78 (2.63) | 7.96 (2.75) | −2.87,0.005 | 0.41 |
| APPS Guilt-proneness | 13.90 (2.74) | 13.48 (2.66) | 14.33 (2.77) | −2.06,0.041 | 0.31 |
| APPS No-concern | 10.67 (2.75) | 10.71 (2.99) | 10.63 (2.48) | 0.20,0.845 | 0.03 |
| K10 | 18.81 (6.54) | 17.82 (6.13) | 19.85 (6.82) | −2.05,0.042 | 0.31 |
| WEMWBS | 48.21 (7.64) | 49.45 (6.81) | 46.92 (8.26) | 2.19,0.030 | 0.33 |

**TABLE 4 |** Correlations (Spearman) between constructs and domains by sex.

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|
| 1. APPS Shame | – | 0.18 | −0.51*** | 0.39*** | 0.47*** | 0.33** | 0.49*** | 0.47*** | −0.54*** |
| 2. APPS Guilt | 0.13 | – | −0.32** | 0.15 | 0.24* | 0.17 | 0.21 | 0.26* | −0.21 |
| 3. APPS No concern | −0.24* | −0.12 | – | −0.31** | −0.40*** | −0.24* | −0.40*** | −0.46*** | 0.52*** |
| 4. APSQ Self-regulation | 0.41*** | 0.10 | −0.15 | – | 0.62*** | 0.41*** | 0.87*** | 0.77*** | −0.53*** |
| 5. APSQ Performance concerns | 0.44*** | 0.35** | −0.20 | 0.57*** | – | 0.42*** | 0.91*** | 0.67*** | −0.36*** |
| 6. APSQ External coping | 0.17 | −0.02 | 0.01 | 0.40*** | 0.18 | – | 0.52*** | 0.40*** | −0.27* |
| 7. APSQ Total | 0.49*** | 0.26* | −0.22* | 0.86*** | 0.88*** | 0.42*** | – | 0.79*** | −0.50*** |
| 8. K10 | 0.49*** | 0.06 | −0.08 | 0.72*** | 0.52*** | 0.43*** | 0.73*** | – | −0.58*** |
| 9. WEMWBS | −0.33** | 0.14 | 0.29** | −0.23* | −0.22* | −0.08 | −0.25* | −0.38*** | – |

*Females above diagonal, males below diagonal. *p < 0.05, **p < 0.01, ***p < 0.001.*

**TABLE 5 |** Partial correlations (Spearman) for APPS Shame- and Guilt-proneness.

| | Shame-proneness partial[a] | Guilt-proneness partial[b] |
|---|---|---|
| APSQ Self-regulation | 0.39*** | 0.09 |
| APSQ Performance | 0.45*** | 0.23*** |
| APSQ External coping | 0.23** | 0.03 |
| APSQ Total | 0.48*** | 0.21** |
| K10 | 0.47*** | 0.13 |
| WEMWBS | −0.44*** | 0.41 |

[a]*Controlling APPS Guilt-proneness;* [b]*Controlling APPS Shame-proneness. **p < 0.01, ***p < 0.001.*

associated with a range of clearly maladaptive self-regulatory outcomes in the elite sport context. Indeed, associations with the APSQ items indicated that shame-proneness was associated with the self-reported tendency to engage in risk taking behavior, the use of substances to cope, issues with irritability and aggression, reduced motivation, and detachment from one's teammates. Discrete experiences of performance related guilt were unrelated to these same problematic self-regulatory and coping strategy outcomes. These findings provide support for the external validity of the APPS, and suggest that athletic performance related shame may be associated with a host of negative sequela for young athletes.

Findings from the conditional process analysis indicated that shame-proneness, but not guilt-proneness, mediated the relationship between general and athlete-specific distress, and that this relationship was not moderated by participant sex or recent mental health help seeking. When interpreted in the light of other findings reported above, this finding (while preliminary and requiring replication) suggests that the effect of athlete shame-proneness is not driven by mental ill health or the observed sex difference in shame, but rather explains unique variance in the relationship between general distress and psychological distress. These findings are underscored given the stringent use of 99% CIs, and the evaluation of parallel mediators (e.g., guilt-proneness and well-being). Consistent with previous literature (e.g., Lutwak et al., 1998) and theory (e.g., Tangney and Dearing, 2002), this highlights the particularly aversive and impactful nature of shame, and warrants both further empirical study and exploration of intervention targets.

In achievement settings, feelings of shame arise when an individual fails to adequately perform a task, and attributes this failure to perceived global incompetence (Weiner, 1985, 1986). Athletes are socially regulated by an array of internally prescribed standards (i.e., from the self, coaches, teammates), and externally prescribed standards (i.e., from the public, media, and social media). In this regard, there is ample opportunity for perceived performance failure among athletes. Given athletic identity is largely based on performance success, shame may be induced by sports performance failure or athletic inability (Lazarus, 2000; Conroy, 2004), especially in shame-prone individuals. Broader assessment of the APPS domains would inform prevalence of athletes experiencing these affective states, and could provide coaching and sports medicine professionals with a tool that aids identification of athletes that may be at risk of experiencing maladaptive failure reactions.

A practical extension of the present study would be examining APPS domains in the context of brief sport-specific interventions,

**TABLE 6 |** APPS Quartiles and corresponding APSQ and K10 indices.

| APPS Shame-proneness quartile | APPS Shame-proneness score | APSQ | | K10 | |
|---|---|---|---|---|---|
| | | *M* (SD) | Category descriptor | *M* (SD) | Category descriptor |
| 1st | 3–5 | 14.00 (3.36) | *"Normal"* | 14.53 (4.02) | *"Normal"* |
| 2nd | 6 | 15.98 (3.93) | *"Moderate"* | 17.65 (5.50) | *"Moderate"* |
| 3rd | 7–8 | 18.00 (4.36) | *"High"* | 19.23 (5.83) | *"Moderate"* |
| 4th | ≥9 | 20.86 (6.79) | *"Very high"* | 22.07 (7.21) | *"High"* |

and situations of maladaptive coping to avoid shame states in particular. One pertinent example is athlete self-handicapping, where an athlete may present oneself with a hindrance or barrier to performance, which is perceived to reduce chances of success or achievement (Snyder, 1990). While self-handicapping is typically perceived as a transgression according to social and moral codes within sports performance, and may elicit guilt feelings (Munroe et al., 1999). Hofseth et al. (2015) found that in elite soccer players, shame-proneness had a direct positive relationship to behavioral self-handicapping, and guilt-proneness had a direct negative relationship to behavioral self-handicapping. Longitudinal studies could look to explore the temporal associations between athlete shame and guilt, self-handicapping, performance and other key variables, including the coach-athlete relationship, and other indices of mental ill health including substance misuse.

Regarding potential intervention, self-compassion-focussed therapies are gaining increasing interest in the sports medicine context (e.g., Mosewich et al., 2019; Walton et al., 2020). Self-compassion approaches seek to develop athlete abilities to engage with distress in a compassionate manner to activate affiliative processing systems, and brief measures of the construct exist, which may be useful in assessing self-compassion in the sports setting (e.g., Raes et al., 2011; Steindl et al., 2021). Previous research has found that self-compassion is negatively correlated with self-criticism ($r = -0.61$) and positively correlated with perceived sport performance ($r = 0.29$; Killham et al., 2018), hence the development of self-compassion skills may reduce the likelihood of experiencing shame. There is emerging evidence (in non-elite settings) that suggests coaching and high-performance staff, including sports psychologists, should build team awareness of how team-based norms of self-compassion evolve, particularly given greater perceived self-compassion within teams is associated with higher *individual* self-compassion (Crozier et al., 2019). As such, investment in focussed professional development for coaching and high-performance staff to enhance team-based cultures of self-compassion (while simultaneously balancing the rigors and expectations of elite performance), may support environments where athletes can gain insights and coping strategies to support their mental skill development in parallel with sporting skills.

The present findings need to be considered alongside several important limitations. The validation sample reported in the present study was comparatively small and lacked diversity. As the sample consisted of junior elite cricket athletes, future research with the APPS is needed across a wider range of sporting disciplines, in addition to testing wider psychometric properties of the scale (e.g., differential item functioning) across salient demographic groups such as culture, age, education, and socioeconomic status. Future work should also consider person-centered approaches to assessing change in athlete APPS scores over time, such as latent growth curve modeling (e.g., Rice et al., 2020b). Also, from a sport-specific perspective, cricketers' experience significantly more day to day performance fluctuation attributable to luck compared to many other sports (Bhanushali and Bagchi, 2020). This means that the cricket context and associated luck (or more specifically, bad luck) may result in cricket players being more likely to question their own abilities in comparison to other athletes, which may in turn influence perceptions of shame and guilt. Accordingly, we call for additional validation of the APPS across representative and diverse athlete populations globally. Such cross-cultural validation efforts are underway with the Sports Mental Health Assessment Tool (SMHAT-1) from the International Olympic Committee (Gouttebarge et al., 2021) and the APSQ (Rice et al., 2020b) used in the present study, which, like the APPS, provide bespoke athlete-centered psychological assessment tools. While this study demonstrated associations between the APPS domains and indices of positive and negative mental health functioning, the implications for indictors of athletic performance and other related variables (e.g., team functioning, depth of coach-athlete relationship, motivation) are unclear, and an important line of future inquiry. Further, data was collected from junior-level elite athletes, and generalization of these findings to senior players or athletes are uncertain. A highlighted above, longitudinal research is required as the present data is cross-sectional in nature, prohibiting analysis of temporal factors. The present study was nested in a larger piece of research, and as such, we were limited in the number of validated scales that could be utilized. The consequence of this is the limited convergent and divergent validity information is available for the APPS domains, and further research using established measures of guilt and shame (e.g., TOSCA, Tangney et al., 2000; PFQ-2; Rice et al., 2018) is needed to explore overlap between the APPS and other widely used scales and domains. Finally, there is an urgent need for the development and evaluation of athlete-specific mental health interventions. Notwithstanding some notable exceptions (e.g., Donohue et al., 2018) randomized controlled trials are needed. While there is growing knowledge related to the unique mental health challenges that elite athlete experience and new individual-based models are being developed and implemented (Rice et al., 2020c), relatively little is known from the existing literature of controlled trials regarding the best type and form of team-based intervention. While self-compassion focussed therapies appear promising, high quality trials are needed.

In conclusion, the present study offers the field a new tool for assessing athlete-specific guilt and shame. While this initial validation study provides robust data on the factor structure of the APPS, more work is required to demonstrate the clinical or performance utility of the scale. Nonetheless, given guilt and particularly shame are known to exert problematic consequences in non-sporting achievement contexts, they are also likely to impact domains of athletic achievement, and thus warrant further applied research.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because we do not have ethics approval to make the data available open access.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by La Trobe University Human Research Ethics Committee (HEC19480). Written informed consent for participation was not provided by the participants' legal guardians/next of kin because Completing the Athletic Perceptions of Performance Scale was deemed low risk. Parents/guardians were encouraged to discuss participation with their child, however participants aged over 16 years were able to consent without parent/guardian approval. A psychologist was present at the time of survey completion, and details of additional external support (either online and phone) were also provided.

## AUTHOR CONTRIBUTIONS

SR was responsible for data analysis and preparation of the manuscript, and played a role in design of the study. MT, LO, KG, and RP contributed significantly to data interpretation and write-up of the manuscript. AS coordinated the study, managed logistics and approvals, and assisted with data interpretation. AK, ML, GM, JO, and PC supported study conceptualization, facilitated data collected, and assisted with ethics approval and post-approval processes. All authors have reviewed and approved the final manuscript.

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# Perfectionism, Self-Esteem, and the Will to Win Among Adolescent Athletes: The Effects of the Level of Achievements and Gender

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This study examined the relationships between perfectionism, self-esteem, and the will to win and the effects of gender and the level of achievement on these variables. A total of 318 adolescents in the age group of 12–19 years ($M = 16.10 \pm 1.01$) completed the self-esteem questionnaire, the will-to-win questionnaire, and the perfectionism inventory. Interstate level (ISL) athletes obtained higher scores than interdistrict level (IDL) athletes on the following variables: self-esteem, the will to win, and four of the eight dimensions of perfectionism (i.e., concern over mistakes, the need for approval, organization, and planfulness). Further, male athletes obtained higher self-esteem and perfectionism (i.e., the need for approval and rumination) scores than female athletes. Self-esteem, the will to win, and the dimensions of perfectionism were positively and significantly interrelated. However, one dimension, namely, perceived parental pressure, was unrelated to any factor except striving for excellence. Further, the will to win, concern over mistakes, high standard for others, and planfulness were unrelated to striving for excellence. The results of the discriminant analysis revealed that there was no significant difference between ISL and IDL athletes (variance explained = 9.480%). Finally, using path analysis showed that Model 3 (perfectionism self-esteem will-to-win) has provided good model fit such as Bentler's comparative fit index (CFI) (0.987), Tucker-Lewis index (TLI) (0.876), normed fit index (NFI) (0.973), and the root mean square error of approximation (RMSEA) (0.097).

**Keywords: need for approval, rumination, planfulness, striving for excellence, parental pressure**

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## INTRODUCTION

A characteristic feature of aspiring sportspersons is their pursuit of the attainment of high levels of performance. They tend to set high standards of performance for themselves, and this helps them accomplish their goals as a part of their pursuit to enhance their performance and skills. However, many athletes set unrealistic goals, and they believe that they need to accomplish them to achieve excellence (Burton and Naylor, 2002). Reportedly, individuals with perfectionistic cognitions often experience excessive anxiety (Lessin and Pardo, 2017). This is primarily the result of a discrepancy between the ideal self and the real self of an individual, and it can have detrimental effects on athletic performance. Several studies have found that a high level of motivation is an antecedent to optimal sports performance. In this regard, the cues that precede these behavioral patterns have been examined, and direction and intensity have been identified as key factors that play a role in action and effort (Iso-Ahola and St. Clair, 2000). The findings of several studies underscore the importance of motivation (Nicholls, 1989). These studies have tended to adopt goal orientation theory as their theoretical framework (Nicholls, 1989; Murcia et al., 2008). According to this theory, there are two types of goal orientations: (a) task orientation (i.e., emphasis on efforts and self-improvement) and (b) ego orientation (i.e., emphasis on outperforming others; Nicholls, 1989; Murcia et al., 2008). Therefore, this study aimed to examine the relationships between the different dimensions of perfectionism, self-esteem, and the will to win among adolescent athletes. This study also aimed to examine group differences (i.e., gender and achievement) in these variables.

## Perfectionism

Perfectionism is defined as "the personal highest standard which accepts excellence in a certain pursuit and rejects anything else" (Thompson, 1995, p. 1,015). Perfectionism is a multidimensional construct that encompasses multifaceted characteristics (Enns and Cox, 2002) and is prevalent among competitive athletes (Dunn et al., 2005). Sports psychologists have been interested in delineating the role that perfectionism plays in sports performance. Some consider it to be an adaptive trait that is shared by Olympic athletes, but others consider it to be a maladaptive trait that adversely affects performance. Therefore, researchers have been interested in resolving these contrasting perspectives (Flett and Hewitt, 2005). Perfectionism can be differentiated into two types, namely, personal standards and evaluative concerns. Personal standards perfectionism is striving for perfectionism that is rooted in personal standards and self-orientation (Dunkley et al., 2000; Blankstein et al., 2008). This dimension yields positive outcomes and affects and enhances performance. In contrast, evaluative concerns perfectionism is characterized by a preoccupation with the mistakes of an individual, self-doubt, and concerns about evaluations of an individual's performance by others. It results in negative outcomes such as anxiety, distress, and negative affect (Stoeber and Otto, 2006). Competitive athletes seek to attain excellence in whatever they pursue. Therefore, the achievement of excellence in a specific pursuit will enhance their sense of self-worth and, eventually, increase their self-esteem (Sonstroem et al., 1991). Slaney et al. (2001) found that normal perfectionism was more strongly correlated with self-esteem compared with neurotic perfectionism. Further, the relationship between normal perfectionism and self-esteem has been found to enhance self-competence and self-acceptance. In contrast, negative perfectionism exacerbates psychological problems such as depression, anxiety, and personality or interpersonal problems (Ghahramani et al., 2011). Based on these findings, the following hypotheses were formulated: there will be a significant difference in the level of perfectionism of (a) boys and girls and (b) those with different levels of achievement ($H_o1$), and perfectionism will be positively correlated with self-esteem and the will to win ($H_o2$).

## Will to Win

The will to win can be defined as a path toward the achievement of personal excellence and success in sports. It can also be defined as an intense urge to accomplish a voluntarily and consciously chosen goal. The will to win also entails tremendous inner strength and persistence toward a goal (e.g., life, sports, or any other endeavor). In one study, basketball players who possessed a stronger will to win were found to be more likely to win a game than their counterparts with a weaker will to win (Dorsey et al., 1980). However, of all the determinants of sports performance, desire and a will to win have been identified as the most influential factors. However, the interactionist approach to personality suggests that a will to win may vary across different sports and athletes with different levels of performance.

Singh and Reddy (2010) examined whether the will to win varies across different groups of athletes ($N = 60$; 15 short-distance runners, 15 long-distance runners, 15 jumpers, and 15 throwers). In the aforementioned study, the will to win was conceptualized as the intensity of the desire of an individual to defeat an opponent or exceed established standards of performance. The researchers found that long-distance runners had the strongest will to win, followed by throwers, short-distance runners, and jumpers. However, in a study that was conducted among 60 female athletes (15 short-distance runners, 15 long-distance runners, 15 jumpers, and 15 throwers), no significant group differences were found (Reddy et al., 2010). They concluded that differences between athletes are contingent on the intensity of their desire to defeat an opponent or exceed established standards of performance. Based on these findings, we proposed the following hypothesis: there will be a significant difference in the strength of the will of an individual to win between (a) boys and girls and (b) those with different levels of achievement (*Ho3*).

## Self-Esteem

Self-esteem refers to the extent to which an individual holds favorable attitudes toward oneself (Rosenberg, 1965). High levels of self-esteem yield positive outcomes (McAuley and Rudolph, 1995; McAuley et al., 2005) and make individuals feel good about themselves (Sonstroem and Morgan, 1989) by enhancing their well-being (Harter, 1993). Self-esteem is also considered to be a type of self-confidence that varies across different contexts (Weinberg and Gould, 2015); therefore, it informs players about evaluations of their own achievements. Several different motivational theories have been used to understand the role that domain-specific self-evaluations play in achievement-related behaviors. Domain-specific self-evaluations play a pivotal role in enhancing sports-centric motivational behavior (Harter, 1978; Nicholls, 1989). The study of Ahmed et al. (2020) highlighted that the adolescent athletes who participated at the national level showed higher levels of self-esteem and the will to win. They also reported a higher dispositional flow, especially in the factors of challenge skill balance, clear goals, and concentration on the task at hand. Besides, male athletes had significantly higher self-esteem and dispositional flow than female athletes. Furthermore, their study showed a significant positive relationship between self-esteem, will to win, and dispositional flow subscales. Several theories have posited that participation in sports and physical exercise and perceived competence are strongly related to intrinsic motivation (Bandura, 1986; Deci and Ryan, 2000). Several research findings suggest that self-esteem is closely associated with motivated behavior in physical activity settings (Goudas et al., 1994) and physical activity behaviors (Welk and Eklund, 2005). In an intervention study that was conducted among 11 to 15-year-old adolescents ($N = 634$), it was found that physical activity reinforces autonomous motives and enhances self-esteem. On the other hand, Tremblay et al. (2010) found that women and men who were more physically active had considerably higher levels of self-esteem than inactive students. High levels of physical activity were associated with higher levels of self-esteem, and this finding was valid, irrespective of the sex or age (range: elementary school to university students) of the participants (Frost and McKelvie, 2005). Another study found that individual sports athletes had higher levels of self-esteem and lower levels of anxiety than team sports athletes. Further, male athletes have been found to possess high levels of somatic anxiety and self-esteem than their female counterparts (Ichraf et al., 2013). Therefore, the following hypothesis was formulated: there will be significant differences in the self-esteem of (a) boys and girls and (b) those with different levels of achievement (*Ho4*).

## Sports in India, Theoretical Frameworks, and the Aim of This Study

In India, physical education (PE) and sports are not compulsory subjects. Therefore, only interested students choose to participate in games and sports. Further, the existing PE curriculum is unstructured and does not reward participation in sports. In addition, it fully depends on the school or the individual whether they want to pursue PE as a subject. Although PE is not compulsory for students, schools located in urban areas are more likely to pursue PE than those in rural and semirural areas (Ahmed et al., 2020). Sports and physical activity have a tremendous impact on the life of an adolescent and have been a major discussion of public health perspectives for a long time. Engaging in sports during adolescence is associated with an active lifestyle and enhances the general well-being. Although adolescence is a developmental period, it is associated with a certain degree of psychosocial vulnerability (Fuentes et al., 2020). Despite the numerous benefits of physical activity, adolescents tend to be less physically active and their participation in sports decreases with increasing age, which generally occurs between the ages of 15 and 16 years. These inconsistencies toward sports participation may be linked to several factors. However, if we relate this to the Indian context, some of these factors include low socio-economic status, lack of family support, peer support, and hardship to access sports facilities. Children rarely receive any encouragement and motivation from their parents to participate in sports. In Indian, parents usually prioritize "*study*" before participation in "*sport*." Furthermore, family culture has also shown to be a strong evidence factor for facilitating propensities of individuals to play sports (Birchwood et al., 2008). Not all places in India have sufficient facilities (playground, stadium, equipment, etc.) to conduct sports activities; therefore, this obligates parents to take their children far away for sports practice. Often, this does not become possible for parents that have difficulties providing such support to their children, i.e., parents with low socio-economic status. Therefore, geographical accessibility (proximity) and affordability seem to be the major determinants of sports participation in adolescents (Eime et al., 2013). Adolescents spend a considerable amount of their free time with their peers as parental influence decreases (Ridao et al., 2021). Adolescence is not always the same in all cultural contexts, being differences between European and Anglo-Saxon countries compared to Eastern Societies (Yeung, 2021), especially for athletes (Sun et al., 2020). However, parents always remain as an important source of support to their children (Gallarin and Alonso-Arbiol, 2012). From this support, they perceive love and affection from their families, which enhances positivity for adjustment and competence (Martinez et al., 2021). Overall, parental practices based on warmth and involvement are related to adolescent competence and adjustment (Queiroz et al., 2020).

The study of Weiss and Amorose (2008) highlighted that concurrently students face major barriers (e.g., unsupportive parents and coaches, gender discrimination, and financial lacuna) that adversely affect their sports performance, growth, and prospects of success. The findings of this study, which examined the levels of perfectionism, self-esteem, and the will to win of adolescent student athletes, were expected to offer valuable information that addresses their need for improved performance. This study also examined gender differences and differences between athletes with different levels of achievement. Across all regions in India, the participation of women in sports appears to be a neglected issue. It is surprising that similar findings have also been reported in many other developed and developing countries. There has been a steep decline in the participation of adolescent girls (14–15 years) in sports (Pate et al., 2007; Bélanger et al., 2009). Therefore, this study, which adopted the competence motivational theory of Harter (1978, 1981) as a conceptual framework, aimed to offer developmentally appropriate statistics of these schools were primariding to the questionnaires were addressed, if these variables an activity ment, and per explanation for motivated behavior, performance, and achievement attrition within the domains of physical activity and sports across the different age groups.

Adolescents possess high levels of self-determination, tend to be drawn to challenges, discover their own strengths and weaknesses, and pursue goals and success (including mental toughness). In this regard, they seek psychological support and motivation from their peers, family members, and society at large. Nonetheless, the unsupportive and unstructured sports environment in India has had a negative effect on their performance, and it is an important issue that should be addressed. Therefore, the primary aim of this study was to examine group (i.e., gender and achievement) differences in perfectionism, self-esteem, and the will to win. Only a few studies have addressed these issues, and none of them were conducted in India. According to competence motivation theory, mastery experiences promote a sense of self-efficacy. Such efforts are also major contributors to desirable outcomes such as self-efficacy beliefs, autotelic experiences, emotional intelligence, enjoyment, and perceived competence. Children tend to continue engaging in an activity for a long period of time when they feel competent and derive enjoyment from their participation (Weiss et al., 2009). Additionally, social agents and contexts play a crucial role in sustaining achievement behaviors among adolescents (Weiss and Amorose, 2008). In summary, competence motivation theory lucidly delineates the role that social agents play in promoting positive attitudes among adolescents by enhancing the motivational levels of athletes and the enjoyment that they derive from participating in an activity (Weiss and Amorose, 2008). Reportedly, a decrease in such scholarship can adversely affect the levels of motivation, enjoyment, and future commitment to an activity of the athletes (Weiss et al., 2009). Therefore, based on a review of the literature and the aforementioned theoretical arguments regarding the participation of Indian youth in sports, this study aimed to determine their levels of perfectionism, self-esteem, and the will to win and examine group (i.e., gender, achievement) differences in these variables.

# METHODS

## Participants

Using a stratified random sampling method, a total of 318 adolescent athletes were recruited from various higher secondary schools in Maharashtra, India. The sample consisted of 188 (47.6%) boys and 130 (52.4%) girls. Their ages ranged from 12 to 19 years ($M = 16.10 \pm 1.01$). Further, they had participated in various interdistrict and interstate games and sports competitions. All the students were recruited from the Indian Council of Secondary Education (ICSE) schools. With regard to their levels of achievements, 143 (44.9%) of them had participated in interdistrict competitions, and 175 (55.1%) of them had participated in interstate competitions (**Table 1**).

## Ethical Considerations

This study was reviewed and approved by the India First Foundation, India. The participants were recruited from various schools, and their participation in this study was completely voluntary. Prior to data collection, the principal investigator of this study met the principals, teachers, and coaches of the school and informed them about the aims of this study. Written informed consent to participate in this study was provided by the athletes, their parents (for minors), and their coaches. All collected data were coded in order to maintain the confidentiality of participants. The student athletes were also informed about the study, and any doubts that they had while responding to the questionnaires were addressed. They were requested to answer all the items in the questionnaires, including the ones that required them to provide their personal information. Further, they were assured that their personal information and responses would be kept confidential.

## Procedure

Standardized assessments were used to collect data. Data were collected from the students of various ICSE schools. A substantial proportion of the data were also collected during the National Volleyball Tournament, which was held at the India First Foundation School in Karjat and Mumbai, India. Data collection was completed by the end of 2015. The athletes were recruited from ICSE schools. Therefore, only the English versions of the questionnaires were administered. The schools were located in Karjat and Mumbai. In these schools, English was the primary medium of instruction and examination. Therefore, the participants could complete these assessments in English.

The demographic characteristics of the participants are presented in **Table 1**.

## Measures

### Self-Esteem

The 10-item Rosenberg Self-Esteem Questionnaire (Rosenberg, 1965) was used in this study. It consists of positively and negatively worded items that assess self-esteem, self-worth, and current attitudes toward oneself. Responses to the items are recorded on a 4-point Likert scale (Strongly Agree = 3, Agree = 2, Disagree = 1, and Strongly Disagree = 0). Items 3, 5, 8, 9, and 10 are reverse scored. Five items are positively worded (e.g., "On the whole, I am satisfied with myself," "I feel that I have a number of good qualities"), and another five items assess negative self-evaluations (e.g., "At times, I think I am no good at all," "I feel I do not have much to be proud of"). Total scores can range from 0 to 30. It has high reliability (0.80). Its internal consistency and test-retest reliability coefficients range from 0.77 to 0.88 and 0.82 to 0.85, respectively (Ahmed et al., 2017). In this study, its Cronbach's alpha was 0.90.

### Will to Win

The 14-item will-to-win questionnaire, which has been developed by Pezer and Brown (1980), was used in this study. It is a sports-specific self-report measure that assesses the extent to which a person desires to achieve a given standard of excellence or defeat an opponent. This questionnaire consists of true–false items. Individual item scores (true = 0, false = 1) should be averaged to compute a total score. Scores that approximate 0 are indicative of a stronger will to win. Seven items are reverse scored (e.g., "I am more likely to swear when we're losing than when we're," "I go into most games thinking we are going to win," "During a game I sometimes feel sorry for opponents"), and seven items are positively worded (e.g., "I hate to lose," "A team can be considered successful without winning," "I don't mind when teammates give <100%"). In a pilot study that was conducted among 254 undergraduates who regularly participated in one of the seven sports, the test-retest (4 months) reliability of this scale was found to be 0.87, and the Kuder–Richardson reliability coefficient was 0.66. In this study, the Cronbach's alpha of this scale was 0.43.

### Perfectionism

To assess the multidimensional facets of perfectionism, the perfectionism inventory (59 items) by Hill et al. (2004) was used. This inventory consists of eight dimensions: concern over mistakes (CM; e.g., "If I make mistakes, people might think less of me"), high standards for others (HSO; e.g., "I usually let people know when their work isn't up to my standards"), need for approval (NA; e.g., "I am over-sensitive to the comments

**TABLE 1 |** Demographic information.

| Level of achievement | | | Types of sports | | | Total |
|---|---|---|---|---|---|---|
| | | | Volleyball | Basketball | Football | |
| Inter district level | Gender | Male | 33 | 22 | 24 | 79 |
| | | Female | 39 | 10 | 15 | 64 |
| | | Total | 72 | 32 | 39 | 143 |
| Inter state level | Gender | Male | 24 | 44 | 41 | 109 |
| | | Female | 27 | 25 | 14 | 66 |
| | | Total | 51 | 69 | 55 | 175 |
| Total | Gender | Male | 57 | 66 | 65 | 188 |
| | | Female | 66 | 35 | 29 | 130 |
| | | Total | 123 | 101 | 94 | 318 |

of others"), organization (O; e.g., "I think things should be put away in their place"), perceived parental pressure (PPP; e.g., "My parents hold me to high standards"), planfulness (P; e.g., "I find myself planning many of my decisions"), rumination (R; e.g., "I spend a lot of time worrying about things I've done, or things I need to do"), and striving for excellence (SE; e.g., "My work needs to be perfect, in order for me to be satisfied"). Responses can be recorded on a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree). All the subscales have excellent internal consistency (range = 0.83–0.91) and test-retest (3–6 weeks) reliability (range = 0.71–0.91).

### Data Analysis

Descriptive statistics (means, SDs, skewness, and kurtosis) are presented in **Table 2**. None of the skewness and kurtosis values exceeded the accepted limits (−2 to +2). This indicated that the assumption of normality was met (**Table 2**).

The demographic characteristics of the participants were examined by computing frequencies and percentages. With regard to the assessments, raw scores were computed in accordance with the instructions outlined in their manuals, and means and SDs were calculated. An independent-samples *t*-test was conducted to examine group (i.e., gender, achievement) differences. Discriminant function analysis was conducted to arrive at a combination of variables that predicts group membership (i.e., participants with different levels of achievement).

This study aimed to develop a model that includes all pertinent variables. Further, rigorous procedures were adopted to ensure that the model is applicable to both male and female athletes. Hence, path analysis was conducted to examine mediation effects, and the maximum likelihood estimation was used.

Model fit was examined by inspecting the results of the chi-squared test, the root mean square error of approximation (RMSEA), Bentler's comparative fit index (CFI), and Tucker-Lewis index (TLI). All the variables were treated as observed variables. This rendered path analysis similar to structural equation modeling (SEM).

By including fewer parameters in the model, we were able to enhance the parsimony of the model and better leverage our sample size. The data were analyzed using SPSS version 20.0. RMSEA values ≤0.08 are indicative of a reasonable fit. CFI and TLI values >0.95 are indicative of an excellent model fit (Kline, 2005).

The proportions of variance explained were ascertained by computing squared multiple correlations ($R^2$). IBM SPSS version 20.0 was used to compute descriptive statistics and conduct correlational analyses, and AMOS version 20.0 was used to conduct SEM.

## RESULTS

The data were analyzed using IBM SPSS (20.0). Descriptive statistics (i.e., means and SDs) were computed. An independent-samples *t*-test was used to examine gender differences and differences between groups with different levels of achievement. Zero-order correlations were computed to examine the relationships between the study variables. Discriminant function analysis was conducted to arrive at a combination of variables that predicts membership to the groups that differ in their levels of achievement. Subsequently, path analysis was conducted (AMOS 20.0). Mediation effects were tested using the maximum likelihood estimation. Model fit was assessed by inspecting the results of the chi-squared test, RMSEA, Bentler's CFI, and TLI. Since the reliability of the variables had already been established, they were treated as observed variables. This rendered path analysis identical to SEM; path analysis can be regarded as a special type of SEM in which only the observed variables are included in the causal model. In contrast, SEM is used to estimate latent variables that are founded upon observed variables. By including fewer parameters in the model, we were able to enhance the parsimony of the model and better leverage our sample size.

Means, SDs, Cronbach's alphas, and correlation coefficients for the study variables are presented in **Table 2**. The magnitudes of the intercorrelations among the variables ranged from weak to strong (−0.005 to 0.616). Moderate to strong positive correlations emerged between all variables except PPP, which was weakly and negatively correlated with all the factors. Further, the will to win was not correlated with SE.

**TABLE 2 |** Descriptive statistics, intercorrelations, and reliability.

| Sl. No. | Factors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Self-esteem | 1 | 0.488** | 0.263** | 0.497** | 0.549** | 0.448** | −0.028 | 0.346** | 0.331** | 0.126* |
| 2 | Will-to-Win | | 1 | 0.204** | 0.399** | 0.476** | 0.351** | −0.100 | 0.224** | 0.274** | −0.005 |
| 3 | Concern over mistake | | | 1 | 0.333** | 0.435** | 0.229** | −0.067 | 0.228** | 0.334** | 0.018 |
| 4 | High standard for others | | | | 1 | 0.709** | 0.593** | −0.017 | 0.472** | 0.526** | 0.116 |
| 5 | Need for approval | | | | | 1 | 0.560** | −0.071 | 0.415** | 0.616** | 0.126* |
| 6 | Organization | | | | | | 1 | 0.104 | 0.568** | 0.427** | 0.281** |
| 7 | Perceived parental pressure | | | | | | | 1 | 0.047 | 0.075 | 0.659** |
| 8 | Planfullness | | | | | | | | 1 | 0.414** | 0.111 |
| 9 | Rumination | | | | | | | | | 1 | 0.127* |
| 10 | Striving for excellence | | | | | | | | | | 1 |
| | Alpha α | 0.896 | 0.427 | 0.771 | 0.621 | 0.653 | 0.596 | 0.732 | 0.439 | 0.541 | 0.914 |
| | Mean | 30.24 | 9.94 | 17.05 | 14.94 | 16.11 | 15.72 | 15.10 | 15.09 | 14.91 | 15.10 |
| | *SD* | 7.27 | 2.49 | 2.40 | 3.08 | 2.75 | 2.81 | 2.73 | 2.80 | 3.20 | 2.87 |
| | Skewness | −0.371 | −0.407 | −1.14 | −0.781 | −1.30 | −0.781 | −1.14 | −0.695 | −0.917 | 1.01 |
| | Kurtosis | −1.07 | 0.202 | 1.86 | 0.432 | 2.59 | 0.770 | 1.61 | 0.322 | 0.769 | 1.33 |
| | Minimum | 13.00 | 2.00 | 6.00 | 4.00 | 4.00 | 6.00 | 4.00 | 5.00 | 4.00 | 5.00 |
| | Maximum | 40.00 | 15.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| Male (Mean) | 30.84 | 9.86 | 28.88 | 27.44 | 30.03 | 30.39 | 30.22 | 26.12 | 27.67 | 26.00 | |
| Male (Standard Deviation) | 6.83 | 2.54 | 5.26 | 5.25 | 5.38 | 4.56 | 4.63 | 4.01 | 5.06 | 5.36 | |
| Female (Mean) | 29.37 | 10.04 | 28.32 | 26.58 | 28.86 | 29.66 | 29.58 | 25.39 | 26.11 | 25.18 | |
| Female (Standard Deviation) | 7.82 | 2.41 | 4.88 | 5.76 | 5.85 | 4.91 | 4.47 | 3.98 | 5.16 | 6.19 | |

*Error for Skewness = (0.137), Kurtosis = (0.273).*
*1, self-esteem; 2, Will-to-Win; 3, concern over mistake; 4, high standard for others; 5, need for approval; 6, organization; 7, perceived parental pressure; 8, planfullness; 9, rumination; 10, striving for excellence. *significant at 0.05 level of confidence. **significant at 0.001 level of confidence.*

**TABLE 3 |** Gender-based descriptive statistics and differences on the variables using independent *t*-test.

| Factor | Gender | | *t*-test for Equality of Means | | | | Eta square |
|---|---|---|---|---|---|---|---|
| | Male (Mean ± *SD*) | Female (Mean ± *SD*) | *t* | Sign. (*p*-value) (2-tailed) | *MD* | *R* | |
| Self-esteem | (30.84 ± 6.83) | (29.37 ± 7.82) | 1.77* | 0.077 | 1.46 | 0.099 | 0.20 |
| Will-to-Win | (9.86 ± 2.54) | (10.04 ± 2.41) | −0.630 | 0.529 | −0.179 | 0.136 | 0.07 |
| Concern over mistake | (28.88 ± 5.26) | (28.32 ± 4.88) | 0.969 | 0.333 | 0.565 | 0.140 | 0.11 |
| High Standard for others | (27.44 ± 5.25) | (26.58 ± 5.76) | 1.37 | 0.171 | 0.856 | 0.142 | 0.15 |
| Need for approval | (30.03 ± 5.38) | (28.86 ± 5.85) | 1.82* | 0.069 | 1.16 | 0.156 | 0.20 |
| Organization | (30.39 ± 4.56) | (29.66 ± 4.91) | 1.37 | 0.171 | 0.737 | 0.160 | 0.15 |
| Perceived parental pressure | (30.22 ± 4.63) | (29.58 ± 4.47) | 1.22 | 0.222 | 0.638 | 0.161 | 0.14 |
| Planfullness | (26.12 ± 4.01) | (25.39 ± 3.98) | 1.59 | 0.111 | 0.730 | 0.172 | 0.18 |
| Rumination | (27.67 ± 5.06) | (26.11 ± 5.16) | 2.67* | 0.008 | 1.56 | 0.149 | 0.30 |
| Striving for excellence | (26.00 ± 5.36) | (25.18 ± 6.19) | 1.25 | 0.212 | 0.815 | 0.150 | 0.14 |

*Male N = 188, Female N = 130, and df = 316. *significant at 0.05 level of confidence.*

## Path Analysis

The path model included three factors (i.e., self-esteem, will to win, and perfectionism). Using AMOS 20.0, SEM was undertaken to test the proposed structural relationships between the study variables. In order to find the best fitting model, three alternative models were evaluated. The fit indices of the alternative models are presented in **Table 4**. The hypothesized model (Model 3) was found to be an excellent fit for the data. The corresponding fit indices were as follows: CMIN/$df$ = 3.988, $df$ = 1, CFI = 0.979, TLI = 0.876, NFI = 0.973, RMSEA = 0.049. The parameter estimates indicated that all the direct path coefficients were significant and in the predicted direction. Self-esteem partially mediated the relationship between perfectionism and the will to win (**Figure 1**).

## Gender Differences

Multigroup analysis was conducted to examine gender differences in the path coefficients. Gender differences were examined by constraining the structural paths of the two models (i.e., for male and female athletes) to be equal.

**TABLE 4 |** Measurement model.

| Regression paths | CMIN/DF | DF | CFI | TLI | NFI | RMSEA |
|---|---|---|---|---|---|---|
| Model 1 (Self-esteem → Will to Win → Perfectionism) | 43.884 | 1 | 0.703 | 0.782 | 0.708 | 0.367 |
| Model 2 (Will to Win → Perfectionism → Self-esteem) | 52.931 | 1 | 0.640 | 1.159 | 0.648 | 0.404 |
| Model 3 (Perfectionism → Self-esteem → Will to Win) | 3.988 | 1 | 0.979 | 0.876 | 0.973 | 0.049 |

**TABLE 5 |** Discriminant function analysis showing differences between levels of achievement in dimensions of all factors.

| Level of achievements | Eigenvalue | Wilks' lambda | Canonical correlation | Chi-square | *df* | Sig. |
|---|---|---|---|---|---|---|
| Inter district level and inter state level | 0.054 | 0.948 | 0.227 | 16.476 | 9 | 0.058 |

*Canonical discriminant functions were used in the analysis.*

An inspection of each path coefficient confirmed that the magnitude of all the associations was similar between male and female athletes. There was no significant gender difference. These results underscore the robustness of the meditation model (**Figures 2**, **3**).

When compared to interdistrict level (IDL) athletes, interstate level (ISL) athletes obtained higher mean scores on the assessments that were used to measure self-esteem and the will to win. They also obtained higher scores on the following dimensions of perfectionism: CM, HSO, NA, O, PPP, P, and R. In contrast, IDL athletes obtained higher scores on the SE dimension. An independent-samples *t*-test was conducted to compare the mean scores that the two groups of athletes (i.e., IDL and ISL athletes) obtained on the assessments that were used to measure self-esteem, the will to win, and perfectionism. There was a significant difference in the self-esteem scores of the ISL ($M = 31.14 \pm 6.77$) and IDL [$M = 29.13 \pm 7.73$; $t_{(316)} = 2.46$, $p < 0.05$, two-tailed] athletes. The magnitude of the mean difference [$MD = 2.00$, 95% confidence interval (CI)] was large ($\eta^2 = 0.27$). This suggests that the ISL athletes had a significantly stronger will to win than their IDL counterparts. There was a significant difference in the will-to-win scores of the ISL ($M = 10.24 \pm 2.32$) and IDL [$M = 9.56 \pm 2.63$; $t_{(316)} = 2.43$, $p < 0.05$] athletes. The magnitude of the mean difference ($MD = 0.679$, 95% CI) was large ($\eta^2 = 0.27$). This indicates that the ISL athletes had a significantly stronger will to win than the IDL athletes. There were significant differences in the following dimensions of perfectionism: CM [IDL athletes: M =, SD =; ISL athletes: M =, SD =; $t_{(df)}$ =, $p < 0.05$], NA [IDL athletes: M =, SD =; ISL athletes: M =, SD =; $t_{(df)}$ =, $p < 0.05$], O [IDL athletes: M =, SD =; ISL athletes: M =, SD =; $t_{(df)}$ =, $p < 0.05$], and P [IDL athletes: M =, SD =; ISL athletes: M =, SD =; $t_{(df)}$ =, $p < 0.05$]. The magnitude of the mean differences in CM ($MD = 1.90$, 95% CI; $\eta^2 = 0.37$), NA (MD = −1.53, 95% CI; eta squared = 0.27), O (MD = −1.07, 95% CI; $\eta^2 = 0.24$), and P (MD = 1.79, 95% CI) was moderate ($\eta^2 = 0.20$). This suggests that ISL athletes obtained significantly higher scores on CM, NA, O, and P. In contrast, differences in HSO, PP, R, and SE were not significant (**Table 3**).

When compared to female athletes, male athletes obtained higher self-esteem, NA, and R (i.e., dimensions of perfectionism) scores. In contrast, female athletes had a stronger will to win.

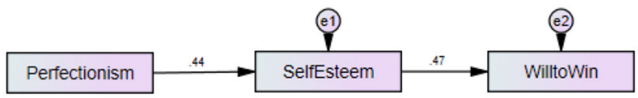


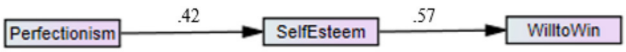

**FIGURE 1 |** Path model depicting direct and indirect relationships between perfectionism, self-esteem, and the will to win.

An independent-samples *t*-test was conducted to compare the self-esteem, will-to-win, and perfectionism scores of male and female participants. There was a significant difference in the self-esteem scores of male ($M = 30.84 \pm 6.83$) and female athletes [$M = 29.37 \pm 7.82$; $t_{(316)} = 1.77$, $p > 0.05$, two-tailed]. The magnitude of the mean difference ($MD = 1.46$, 95% CI) was large ($\eta^2 = 0.20$). This suggests that male athletes had significantly higher levels of self-esteem than female athletes. With regard to NA, there was a significant difference between male ($M = 30.03 \pm 5.38$) and female athletes [$M = 26.11 \pm 5.16$; $t_{(316)} = 1.16$, $p > 0.05$, two-tailed]. The magnitude of the mean difference ($MD = 1.46$, 95% CI) was large ($\eta^2 = 0.20$). This indicates that male athletes had a significantly greater NA than female athletes did. Further, there was a significant difference in the R scores of male ($M = 27.67 \pm 5.06$) and female athletes [$M = 28.86 \pm 5.85$; $t_{(316)} = 1.56$, $p < 0.05$, two-tailed]. The magnitude of the mean difference ($MD = 1.46$, 95% CI) was large ($\eta^2 = 0.30$). This suggests that male athletes ruminated to a significantly greater extent than female athletes did. Differences in the will to win [Males: $9.86 \pm 2.54$, Females: $10.04 \pm 2.41$, $t_{(316)} = 0.630$, $p < 0.05$, two-tailed], CM [Males: $28.88 \pm 5.26$, Females: $28.32 \pm 4.88$, $t_{(316)} = 1.56$, $p < 0.05$, two-tailed], and HSO [Males: $27.44 \pm 5.25$, Females: $26.58 \pm 5.76$, $t_{(316)} = 1.37$, $p < 0.05$, two-tailed] were significant. Differences in O [Males: $30.39 \pm 4.56$, Females: $29.66 \pm 4.91$, $t_{(316)} = 1.37$, $p > 0.05$, two-tailed], PPP [Males: $30.22 \pm 4.63$, Females: $29.58 \pm 4.47$, $t_{(316)} = 1.22$, $p > 0.05$, two-tailed], P [Males: $26.12 \pm 4.01$, Females: $25.39 \pm 3.98$, $t_{(316)} = 1.56$, $p > 0.05$, two-tailed], and SE [Males: $26.00 \pm 5.36$, Females: $25.18 \pm 6.19$, $t_{(316)} = 1.25$, $p > 0.05$, two-tailed] were not significant (**Table 3**).

Canonical discriminant functions were used in the analysis. Discriminant function analysis was conducted to arrive at a combination of variables that predicts membership to the two


| Path Directions | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|
| Self-Esteem ← Perfectionism | .150 | .022 | 6.777 | *** |
| Will-to-Win ← Self-Esteem | .149 | .025 | 5.961 | *** |

**FIGURE 2 |** Path analysis of the latent construct using data obtained from male athletes.




| Path Directions | Estimate | S.E. | C.R. | P |
|---|---|---|---|---|
| Self-Esteem ← Perfectionism | .168 | .032 | 5.332 | *** |

**FIGURE 3 |** Path analysis of the latent construct using data obtained from female athletes.

groups of participants who differed in their level of achievement. The results (Wilks' $\lambda = 0.948$) revealed that the model explained only 9.480% of the variance. The $p$-value was $>0.05$; this indicated that the model was not significant and that there was no significant difference between the two groups. Further, the group centroids were significantly different (distance: higher centroid = 0.170 [ISL], lower centroid = −0.245 [IDL]) (**Table 5**).

## DISCUSSION

The overarching aim of this study was to examine the relationships between the will to win, self-esteem, and perfectionism. Further, to examine these relationships using rigorous methods, path analysis was conducted. The analysis was conducted using the entire dataset as well as the stratified data (i.e., based on gender).

### Level of Achievement

Achievement was differentiated into two levels: IDL and ISL. Significant group differences in self-esteem and the will to win were found. Further, there was no significant difference in any of the dimensions of perfectionism. Group differences in self-esteem were significant. ISL athletes obtained higher scores than IDL athletes (Russell, 2001).

Self-esteem is defined as self-assessment and self-evaluation (Sonstroem and Morgan, 1989; McAuley and Rudolph, 1995; McAuley et al., 2005). People with high self-esteem hold favorable attitudes toward themselves (Rosenberg, 1965). In this study, higher self-esteem scores were obtained by ISL athletes (i.e., the group with a higher level of achievement). Therefore, this finding can be attributed to their level of achievement, playing status, and the level at which they had been competing. Athletes who participate in high-level competitions also have a better quality of life (Fox, 1998), and this in turn nurtures situation-specific self-confidence, which is often regarded as self-esteem (Weinberg and Gould, 2015). This strongly informs how players evaluate their own achievements. An increase in the perceived physical value of a person also enhances self-esteem (Biddle, 1995) and goal-orientation (Duda, 1989). Motivation is a strong antecedent of achievement-related behavior, especially in relation to sports, and it plays a crucial role in cultivating such behaviors (Harter, 1978; Deci and Ryan, 1985; Nicholls, 1989). Therefore, this may be another reason why ISL athletes obtained higher self-esteem scores than IDL athletes.

Further, group differences in the will to win ($t = 2.43$, $p < 0.015$) were significant; ISL athletes obtained higher mean scores than IDL athletes (Russell, 2001). This finding is also attributable to their level of achievement, playing status, and the level at which they had been competing. Isolating the factors that are important determinants of participation in high-level competitions is a complex task. However, the will to win is considered to be one of the strongest determinants of achievement-related behaviors among athletes. The will to win is defined as an intense desire to accomplish something, achieve personal excellence, and succeed at sports. Moreover, the achievement of excellence is indubitably a product of substantial commitment, motivation, and willpower. They nurture a sense of internal strength and persistence toward the goals of an individual across different life domains (e.g., sports). Studies have also found that, once athletes begin to play in high-level competitions, they learn to cope with fatigue and pain, develop strategies to achieve their goals, and stay motivated. All these factors are prerequisites for winning a competition (Durand-Bush and Salmela, 2001). Notably, high levels of commitment can result in burnout in individuals with perfectionist traits. Therefore, this occurrence imbalances individual's emotion. The higher scores that were obtained by ISL athletes are consistent with this conceptualization. One study found that basketball teams with a stronger will to win were more likely to win a game than their weak-willed counterparts (Dorsey et al., 1980). However, of all the determinants of sports performance, desire and the will to win have been listed as the most influential factors. However, the interactionist approach to personality suggests that the will to win may vary across different sports and athletes with different levels of performance. Additionally, in India, sports are not as advanced in developing countries (e.g., infrastructure) as in other developed countries, and athletes often face various impediments that hinder their participation in sports. All aspiring athletes seek to excel at their chosen sport. Young athletes often try to convince their parents to allow them to participate in future competitions by demonstrating good performance. When they perform well, they gain popularity among their peers and within their communities, and they also aim to participate in high-level competitions. Therefore, this may be one of the reasons why ISL athletes reported a stronger will to win. Further, ISL athletes obtained higher means on the CM, NA, and O dimensions of perfectionism. The relationship between perfectionism and sports performance has always puzzled researchers.

The CM dimension of perfectionism is defined as a tendency to react negatively to the errors of an athlete. Athletes are quite conscious about their reputation, and they often equate mistakes with failure and believe that making any mistake will adversely affect their prestige (Frost et al., 1990). However, CM is linked to various factors such as parental pressure, coach pressure, high expectations from peers, and pressure from the federation/club/authorities of an athlete. Studies have found that authoritarian parenting is highly correlated with unhealthy perfectionist orientations among sportspersons (Gotwals et al., 2010). This may be one of the reasons why this cohort obtained higher mean scores on this factor.

When compared with IDL athletes, ISL athletes obtained higher scores on the NA dimension. Human beings possess an inquisitive and ambitious behavior when combining the thoughts and behavior resulting from high outstanding expectations and performances. Such behaviors are characteristic features of elite athletes. They are also more task-oriented and focused on excelling at their chosen sport. Blaney and Kutcher (1991) have propounded that NA is more strongly linked to sociotropy than to dependency. In other words, elite athletes are sensitive to appreciation, criticism, and support (Blaney and Kutcher, 1991). NA is defined as the tendency to seek validation from others and be sensitive to criticism.

Organization is defined as the tendency to be disciplined, be punctual, and adhere to a plan or schedule to enhance the athletic performance of an individual. Wanting to excel at sports is regarded as a healthy and positive type of perfectionistic goal (Stoeber and Otto, 2006) that is strongly influenced by parenting style (Speirs Neumeister, 2004). Indian adolescents try to meet parental expectations and demands by enhancing their performance (Stoeber and Otto, 2006). Therefore, ISL athletes may have obtained higher O scores. An authoritative parenting style has been linked to both positive and negative outcomes (Mouratidis and Michou, 2011). Continuous successes enhance motivation, but failures result in punishment and frustration (Deci and Ryan, 2012). Therefore, further research is needed to better understand this phenomenon and identify the factors that influence the development of organizational tendencies in young athletes.

There were significant gender differences in R. Indian adolescents spend more time on academics than on other extracurricular activities. This is also what parents expect and appreciate. Therefore, it is difficult for them to get parental permission to participate in sports/tournaments. This may be a reason why male athletes obtained higher R scores than female athletes. R is defined as the tendency to obsessively worry about past errors, less-than-perfect performances, and future mistakes. Adolescents may feel anxious about losing a tournament because it can adversely affect the perceptions of their parents about them and their likelihood of being permitted to participate in sports/tournaments in the future. Egan et al. (2013) found that there is a significant relationship between R and CM. In India, the rate of participation in sports is higher among men than among women. Therefore, male athletes may have obtained higher R scores than their female counterparts. Adolescence is a developmental period that is characterized by positivity, vitality, and creativity. They wish to excel at the things that they pursue in order to win the approval of their families and friends. In this regard, parental criticism is a crucial predictor of social anxiety (Nolen-Hoeksema, 2000) and depression (Kocovski et al., 2005; Rukmini et al., 2014). Further, Kocovski and Rector (2007) found that failure is a strong predictor of depressive symptoms. Rumination has also been linked to perfectionism and failure (Harris et al., 2008). Therefore, further research is needed to address these ambivalences in the literature.

### Strengths and Limitations

As a strength, this study provides evidence on the relationships between the different dimensions of perfectionism, self-esteem, and the will to win among adolescent athletes. The study also helped us to comprehend the underpinning attributes that herald male athletes to obtain higher self-esteem and perfectionism than their female counterparts. Striving for excellence has remained a pivotal aspect to aspiring athletes for enhancing their performance. Besides, *parental support* significantly contributes to the success of the children in their endeavors. On the contrary, *parental pressure* is also detrimental to the mental health and motivation of the children. Therefore, in this context, the present study provided details on how perceived parental pressure is associated with striving for excellence and leads toward a decline in their performance. This research has the potential to help PE teachers and sports coaches to allocate strategies for adolescent athletes to obtain excellence in their performance while perceiving parental pressures. Further, this resulted in restricting adolescents' progress in athletic endeavor. Despite the strengths mentioned earlier, this study has several limitations. First, the sample used for analysis is gender-unbalanced (female 52.4%; male 47.6%). In the future, more responses from male athletes should be garnered for analysis. Further, low generalizability of the results has also been presumed in this study to be due to the few participants per sport. Therefore, this study warrants future studies with more participants in each sports group. Besides, this study has invited participants (interdistrict and interstate games) from Maharashtra (state) only, which is considered a limitation. To get a true scenario of the relationships between the different dimensions of perfectionism, self-esteem, and the will to win among adolescent athletes, a study recruiting athletes from different parts of India will enhance its generalizability.

## CONCLUSION

In sum, the present findings delineate the relationships between the three latent variables (i.e., the will to win, self-esteem, and perfectionism). The present findings also specify the variables that differed as a function of gender and the level of achievement. Importantly, the results underscore the validity of the structural model, which was found to be an excellent fit for the data and offer insights into the effects of gender on this model.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

## ETHICS STATEMENT

Permission to conduct this study was obtained from the India First Foundation School. Written informed consent to participate in this study was provided by the athletes, and their coaches.

## AUTHOR CONTRIBUTIONS

MA: study design, data collection, data analysis, and drafting of the manuscript. SB: data collection, data entry, and drafting of the manuscript. GL and WY: drafting of the manuscript. All authors contributed to the article and approved the submitted version.

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