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# Learning and skill acquisition in sports: Theoretical perspectives

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# Learning and skill acquisition in sports: Theoretical perspectives

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# Editorial: Learning and skill acquisition in sports: theoretical perspectives

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Editorial on the Research Topic
Learning and Skill Acquisition in Sports: Theoretical Perspectives

## Introduction

The sports literature offers a diverse selection of theoretical views that attempt to explain how athletes improve with practice. This topic has significant implications for coaches, practitioners, and athletes themselves. Faced with the complexity of this subject, a common tendency is to simplify the issue by categorizing within a dichotomy (1), as evidenced by the common distinction between frameworks based on mental models or representations (e.g., information processing), on the one hand, and ecological approaches (e.g., ecological dynamics), on the other. While the former theoretical frameworks emphasize cognitive factors as keys to performance and improvement, the latter emphasize the relationship between the individual and the environment. The debate between these opposing perspectives has dominated discussions in sport psychology and movement science for over four decades. As suggested by Ranganathan and Driska in the present Research Topic and reinforced by the review conducted by Ashford et al. (2), both the information-processing and ecological-dynamics perspectives tend to generate data, terminology, and interpretations aligned with their respective frameworks.

Despite these binary perspectives and ongoing debates, the validity of the proposed dichotomy is not entirely clear, and how these views differ from or complement each other remains unsettled (2, 3). Moreover, several other theoretical perspectives on learning and skill acquisition in sports may not neatly align with the dichotomy between cognitive models and ecological frameworks.

These issues inspired the current Research Topic, in which scholars were invited to shed light on various approaches to skill acquisition and learning in sports. In the following, we attempt to summarize and offer some conclusions based on the various contributions.

## Theoretical comparisons and commentaries

Koester addressed the ongoing debate between dynamic systems theory (DST) and symbol processing accounts (SPA), highlighting the limitations of both approaches not only from a theoretical standpoint but also in terms of practical consequences for skill learning. He argued for a more comprehensive perspective to support skill learning and rehabilitation, advocating an action-centered perspective and a cognitive future of motor control and learning. Gottwald et al. evaluated the information-processing and ecological-dynamics approaches in the context of focus of attention in skill acquisition. The authors provided a detailed review of relevant research and asserted that the functionality of an appropriate focus of attention is predominantly addressed from an information-processing perspective, with less emphasis from an ecological standpoint. To address this, the authors suggested a novel and more flexible perspective called "Ecological Dynamics Account of Attentional Focus," accompanied with practical recommendations. In their contribution, Ranganathan and Driska raised the question of whether premature theorizing negatively influences skill acquisition research. Discussing the ongoing debate between the information-processing and ecological-dynamics approaches, the authors contended that the limited data on skill acquisition research impedes the conclusive determination of the quality or utility of these respective theories. They went on to provide recommendations for the research field, from both a researcher's and a practitioner's perspective.

## Ecological approaches

A prevalent theme across many articles is the application of the ecological-dynamics framework to skill acquisition, from specific sporting examples to a broader consideration of practice design. For example, Ziv illustrated how racecar driving can be understood by considering the driver, the car, and the racecourse as an interconnected system. From this perspective, skill is considered in terms of the constraints faced by the driver and the perception of affordances (such as passing, braking). O'Sullivan et al. discussed the application of an ecological framework in a case study of a youth football club. In particular, they highlighted the importance of considering sociocultural constraints in player development. Similarly, Rothwell et al., in their case study of a wheelchair rugby team, illustrated how the transfer of knowledge between coach and player can be understood from an ecological perspective as a bidirectional self-organizing system. Addressing the general issue of skill acquisition, Myszka et al. presented a conceptualization of skill acquisition as a problem-solving activity, where performers strive to find the best movement solution to achieve their goal under ever-changing constraints. Finally, Chow et al. offered reflections on how the ecological-dynamics theory can be applied in coaching and practice design. The authors addressed some common concerns including the overusing of jargon, quantifying improvements over time, and giving up control as a coach.

## Beyond the dichotomy

The diversity of philosophical and theoretical perspectives significantly contributes to the advancement of research on skilled movement in sports, moving beyond information processing and ecological dynamics. Engelsrud's work served as an example, showcasing how a phenomenology-informed approach can explore movement experience in yoga practice, emphasizing bodily resonances and sensuous interactions among individuals. Similarly, the study of Stien et al. on non-verbal, visual feedback in resistance training demonstrated the application of this approach to traditional skill adaptation research and practice design. Notably, this novel method blurs and eliminates conventional distinctions between internal and external stimuli and feedback, especially when considering alternative experimental setups and conceptualizations. While there is an ontological resemblance to ecological psychology, it is crucial to acknowledge the divergence in epistemic traditions. Future research should explore how these perspectives can mutually inform theory, research, and practice.

The significance of understanding an athlete's past development and its influence on future learning and skill development in sports was evidenced by the work of Papastaikoudis et al. Through their examination of childhood experiences and psychological skills among youth athletes, they underscored the significance of considering past experiences and psychological resources when designing appropriate learning environments and practice designs. Taking this idea further, Rossing et al. proposed a conceptualization of learning through sports that extends beyond the traditional notion of movement learning. They perceived sports participation as a situated and social practice, where diverse meanings are experienced and negotiated, significantly influencing the lives of young individuals. Drawing from their case study within disability sports, they present examples that could compel movement scientists to be highly attentive to the social context's influence on learning and skill acquisition. This extends beyond the acquisition and adaptation of sport-specific skills, prompting a reconsideration of our preconceptions about what constitutes appropriate session designs.

Finally, adopting a macroscopic lens, Herrebrøden and Bjørndal explored the (in)significance of youth international experience for senior success in football across six European countries and various playing positions (see also their corrigendum).

# Conclusion

The current contributions offer several takeaway messages. Notably, empirical studies can be guided and interpreted through the lens of different theoretical frameworks. This was most often exemplified by ecological approaches, which can be applied to explain a variety of findings and phenomena, including ones that have traditionally been associated with information-processing views, such as attentional focus effects and knowledge transfer.

However, some theoretical approaches do not readily fit into the dichotomy of processing-based vs. ecological approaches. The field of skill acquisition in sports is still in its infancy, and more work will aid the evaluation of theoretical frameworks. In light of the current Research Topic, we hope that the future literature will see diverse contributions, both empirical and theoretical, addressing various aspects related to learning in sport contexts.

## Author contributions

HH: Writing – original draft, Writing – review and editing. RG: Writing – original draft, Writing – review and editing. TS: Writing – original draft, Writing – review and editing. CT: Writing – original draft, Writing – review and editing.

## 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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ORIGINAL RESEARCH
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# Youth International Experience Is a Limited Predictor of Senior Success in Football: The Relationship Between U17, U19, and U21 Experience and Senior Elite Participation Across Nations and Playing Positions

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Athlete participation in youth international competitions is often regarded as crucial to the attainment of future success. However, the link between participation and performance in sports at youth levels and senior levels is unclear at best. To understand this relationship better we conducted two studies of male football players. In Study 1, we examined adult performance at the upper levels of football using a factor analysis and identified the characteristics that define what we termed a "Super Elite" level, which is the highest level of participation. This outcome measure was used in Study 2 to explore further the link between youth international experience and athletes' Super Elite experience. Overall, our results indicated that youth international experience is a limited predictor of participation at the Super Elite level of football. Participation at the U21 level was the strongest, most consistent predictor of Super Elite level participation. U17 participation was found to be either an insignificant or a negative predictor of subsequent participation in international football. The effect of U19 participation on later participation was partly significant, but weaker than the effect of U21 participation, and depended on the national context and the playing positions of the athletes. When looking at the effect of different youth career types, careers involving U21 international experience were the strongest predictors of later careers as Super Elite athletes. National governing bodies that want to ensure success in talent identification and development should therefore consider focusing fewer resources on youth international competitions in age categories before adulthood. A total of 1,482 players who had national football team experience at either the U17, U19, U21, or senior levels were included in our studies.

**Keywords: talent identification, talent development, athlete development, elite sport systems, youth sport**

## INTRODUCTION

Sport organizations have focused increasingly on ways to identify and develop early athletic talent (Till and Baker, 2020). National governing bodies, for example, use considerable resources on talent identification and development programmes each year, including support for youth international competitions (Schroepf and Lames, 2018). How well a country's youth international teams (U-teams) perform is often seen as a key indicator of talent development productivity, and an indicator of likely future international success at the senior level. However, the relationship between youth sport performance and success in senior sport careers remains uncertain at best, both at an individual and team level (Johnston et al., 2018). This is complicated by the fact that talent identification and development systems vary between distinct sport cultures and between sport organizations (Andersen et al., 2015). Performance requirements, too, differ across playing positions and tactical formations (Gil et al., 2014; Modric et al., 2020).

Barreiros and Fonseca (2012) retrospectively examined the relationship between Portuguese elite athletes' involvement in international competitions in football, volleyball, swimming, and judo. The percentage of international senior athletes who had never participated in any international youth competition ranged from 6 to 44%, depending on the sport and the gender of the athletes. In team sports, particularly, a substantial number of international senior athletes had no international experience during their time as youth athletes. Barreiros et al. (2014) also prospectively examined athletes in those same sports across squads that were selected for international games. The overall results showed that only a third of athletes who participated at the international pre-junior level (U14/U15/U16) also participated as senior international players. In basketball, the best senior players in Europe were found not to have had more international youth experience compared to their lower-level counterparts (Kalén et al., 2017). In studies of athletics, only 17% of the male sprinters and 21% of the female sprinters included in the top-50 ranked athletes in the U18 category were able to reach a later ranking among the top 50 senior athletes in the sport (Boccia et al., 2020). Similarly, only 8% of male jumpers and 16% of female jumpers among the top-50 ranked athletes at the age of 16 years were able later to reach a top-50 senior ranking (Boccia et al., 2021a). Only 6 and 12% of male throwers and 16 and 24% of female throwers ranked in the top 50 athletes in the age categories of 16 and 18 years, respectively, were later able to achieve a similar top-50 status in senior elite athletics (Boccia et al., 2021b).

In contrast, Li et al. (2018) found that for junior athletes in combat sports, winning an international medal was a significant predictor of whether they would later win international senior medals. Similarly, Bjørndal et al. (2018) examined athlete progression in Norwegian handball national squads and showed that athletes who played in youth international competitions were later more frequently represented at the senior national team level, compared with athletes who had no youth international team experience. However, the *number* of match appearances in these instances was not associated with later success at the senior level.

Similar studies of German football suggest that approximately a third of youth international players (Güllich, 2014) to a half of youth international players (Schroepf and Lames, 2018) will become senior professionals. This suggests that there is a limited relationship between youth international experience and senior success in football. However, the predictive value of youth participation depends strongly on the type of youth international career in question. Player participation in the higher U-team age categories (for example, the U21 category) has been found to be a relatively successful indicator of later career achievements in senior football (Schroepf and Lames, 2018).

Overall, the findings we reviewed varied considerably by sport, gender, and by country. The inconsistencies and variations we found were, in part, due to discrepancies in the methodological approaches used by researchers (e.g., Boccia et al., 2020). Several studies, for instance, used descriptive statistical approaches (e.g., Barreiros et al., 2014) that lacked appropriate significance testing, and this made it difficult to measure effect sizes across the studies and across the different populations. Further, many of the sport studies were vaguely reported, which made it difficult to compare the findings accurately. Schroepf and Lames (Schroepf and Lames, 2018), for example, defined football success as "reaching [a] professional level in first or second Bundesliga as well as in first or second top European leagues" (p. 407). After reading this paper, we were unsure which specific European leagues had been included in their definition and measurement of professional status or player success. This was disappointing because the information was pertinent to our study.

The aim of our study was twofold. In Study 1, we sought to define the concept of senior elite participation and to create an outcome measure of participation at the highest levels of football using factor analysis. This defined outcome measure was then used as the basis for Study 2, in which we investigated the links between senior elite participation and international participation at the U17, U19 and U21 levels, across playing positions and nations. Our study was pre-registered on the Open Science Framework platform: https://osf.io/xd3rf/.

## STUDY 1: DEFINING SENIOR ELITE PARTICIPATION IN FOOTBALL

Before discussing what factors *predict* senior elite participation, it is important first to *define* what senior elite participation is. This is a challenging and complex process because of the different terminologies used in sport. Swann et al. (2015) note, for example, that football is a particularly competitive field and that all players from all top four tiers in England can be described as "professionals". This, necessarily, makes the term inadequate as a precise classification of football elites. However, the level at which an athlete competes on a regular basis can still be regarded as the best indicator of a performance standard (Swann et al., 2015). In our present study, we therefore sought to identify the competitive categories that we could group together as an outcome measure of senior elite participation at the highest levels.

**TABLE 1 |** Pearson correlation between numbers of games in various categories of male elite football.

| Measure | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Sr. Ntl. Team | 1 | 0.619** | 0.129** | 0.746** | 0.512** |
| 2. Top 5 | 0.619** | 1 | 0.012 | 0.655** | 0.523** |
| 3. Rank 6-10 | 0.129** | 0.012 | 1 | 0.134** | 0.350** |
| 4. CL | 0.746** | 0.655** | 0.134** | 1 | 0.416** |
| 5. EL | 0.512** | 0.523** | 0.350** | 0.416** | 1 |

**Correlation is significant at the 0.01 level (2-tailed).*

## PROCEDURE, DATA ANALYSIS, AND RESULTS

Using online football databases, we identified 1,482 male football players from Denmark, Norway, Sweden, Belgium, Germany, and Portugal who had international football experience and gathered data on their participation in elite football. We then checked the trustworthiness of our data via a reliability test which is described in **Appendix A**. A full description of our participants and data collection is provided in Study 2.

Based on our reliability check, and because we were interested in football participation at the highest levels, we used player participation in the following events as potential options to define an outcome measure of *elite participation* in our study: (a) Senior international team matches; (b) the Champions League (CL); (c) the Europa League (EL); (d) the top five leagues in Europe; and (e) leagues ranked 6-10 in Europe. These competitive domains indicate a certain level of professional "success" in football but using each of them as separate outcome measures would have been analytically cumbersome. Instead, we hoped to make the process of hypothesis testing easier by reducing the outcome measures to one *Super Elite* factor that could be used as an outcome measure in this study. Hence, we took an exploratory approach to factor analysis based on participation data (i.e., how many appearances the recruited players had made in the selected competitive categories).

As shown in **Table 1**, most of the five variables we selected to define an elite player level in this study appeared to be significantly correlated. These correlations were subsequently confirmed to have a Kaiser-Meyer-Olkin value of 0.705, indicating sample adequacy, and a significant correlation value when tested with Bartlett's Test of Sphericity ($p < 0.001$). We therefore regarded the numeric outcome variables as well-suited to factor analysis.

A principal components analysis (PCA) was deemed appropriate for our purpose of reducing the potential number of outcome measures in the current study (Jolliffe and Cadima, 2016). This analysis resulted in two components with an eigenvalue >1. The first component explained a substantial 56% of the variance, while the second explained 21.6%. We used Direct Oblimin rotation to allow for correlation among factors. The resulting solution suggested that four variables could potentially be loaded on the first factor. These variables were appearances in the CL, EL, Top five leagues, and a senior national team. To facilitate our interpretation of the components and to test their robustness as a single unit, a reliability analysis was conducted with these four variables as part of the same scale. The calculated Cronbach's alpha value of 0.48 was below the recommended cut-off value of .7. However, the output suggested a value of .77 if one item–namely, appearances in the Top five leagues–was deleted. We therefore decided to use the remaining three variables as part of the same factor to measure participation in elite football, namely: CL, EL and senior national team appearances. For the sake of completeness, we ran a reliability analysis on the remaining two factors (appearances in the top five leagues, and the leagues ranked 6 to 10, respectively). This provided further confirmation that they were too poorly related to be included as part of the same factor in this context.

To facilitate analysis and interpretation in our study, we decided to use the first factor from our factor analysis as the outcome measure for all our hypothesis testing. Inspired by Collins et al. (2016), we named our outcome component a 'Super Elite' level, because we regarded international appearances at the senior level, CL, and EL as some of the most prestigious levels of male competitive football.

## STUDY 2: THE LINK BETWEEN YOUTH INTERNATIONAL EXPERIENCE AND SUPER ELITE PARTICIPATION

In Study 2, we sought to identify the predictors of participation at the senior elite level, both categorically and numerically. Specifically, we wanted to answer two research questions.

Our first question was: What predicts whether players will achieve Super Elite *status* (i.e., participation in one or more senior national team games, CL games and/or EL games, defined as "yes" or "no")? To answer to this question, we used international participation in a U17, U19 and U21 team – both categorically (i.e., *status*, "yes" or "no") and numerically (i.e., the number of games) – as our main predictor variables. Two relevant player characteristics were included so that we could examine how these interacted with the main predictors, namely player nationality and playing position. In addition to investigating the separate U-team predictors, we tested the effect of various U-team career types (i.e., combinations of U-teams represented) on Super Elite participation.

Our second question was: What predicts the number of Super Elite appearances players will achieve (i.e., the total number of games played in a senior international team, the Champions League and the Europa League) once they have reached this top level? This latter research question is related to our first research question, but at the same time they are distinct: a relatively substantial number of athletes may appear at the top levels at some point, but relatively few of these manage to achieve numerous appearances at the highest levels of competition (Güllich and Emrich, 2012). To answer our second question, we conducted subsample analyses by only including the players who had played one game or more at the Super Elite level ($n = 482$). Due to the more limited sample size in the Super Elite sample, we only used the main U-team variables (i.e., U17, U19, and

U21 status and appearances) as our predictors of the number of games, without the inclusion of player position and nationality, and with no statistical test of U-team career types.

The following hypotheses related to the first research question, using our full sample: (H1a) A player's U17, U19 and U21 status will separately predict his Super Elite status, and the predictors will interact with nation cluster and playing positions; (H1b) A player's U17, U19 and U21 appearances will separately predict his Super Elite status, and the predictors will interact with nation cluster and playing positions; and (H1c) U-team careers that involve more than one U-team and/or U21 participation will be the strongest predictors of players' Super Elite status.

The following hypotheses related to the second research question, concerning the Super Elite players only: (H2a) U17, U19 and U21 status will separately predict the number of Super Elite appearances; (H2b) U17, U19 and U21 appearances will separately predict Super Elite appearances.

## Participants and Context

Our study sample included 1,482 male footballers born between 1990 and 1995. All players had a minimum of one official international appearance for their country. We recruited players from six different countries and grouped these into two clusters: (a) Scandinavian countries (Denmark, Norway, and Sweden); and (b) "Top nations" (Belgium, Germany, and Portugal–e.g., nations that were in the top 10 UEFA country coefficients list during 2020/2021 (https://www.uefa.com/nationalassociations/uefarankings/country/#/yr/2021).

The decision to include and group Scandinavian countries together into one nation cluster was driven by key contextual insights. Scandinavian nations share similar characteristics, including population size, social welfare state systems, and broad-based voluntary sport movements that serve as the basis for elite sport development (Andersen and Ronglan, 2012; Bjørndal et al., 2015). Our intention was therefore to compare Scandinavian countries, collectively, with more densely populated and highly-ranked football nations. The Top nations in our sample were chosen for pragmatic reasons: these countries had reliable national team statistics for individual players, and this information was available on their respective federations' web pages (see **Appendix A** for an elaboration on our process of checking data reliability and how this affected the recruitment process of our study). We were not able to obtain reliable national team statistics for other European Top nations (e.g., England, Spain).

The recruited players all had one or more appearances for the following national teams: Under 17 (U17), Under 19 (U19), Under 21 (U21), and/or Senior.

Our recruitment was based on these team categories for several reasons. First, official tournaments (such as the UEFA European Championships) are hosted for these defined age group categories. Being selected to these teams is therefore prestigious and the likelihood of finding reliable data online was assumed to be high. Second, other U-team configurations are used and prioritized differently across nations. Denmark, for example, has no U15 team, and Sweden has no U20 team. Hence, we were interested specifically in team categories that would facilitate cross-nation comparisons.

We ran *a priori* power analyses using the statistical software G*Power to ensure that our sample included enough players in the least frequent positions (e.g., goalkeepers). Different scenarios were used for our power calculations because of the diversity of our analyses. Based on our power analyses, we sought to include a minimum of 90 players for each position. We also wanted to focus on footballers who were old enough to have had the opportunity to achieve success at the international senior level. Data were therefore collected for male players born between 1990 and 1995 as this was expected to provide us with a sufficiently large total sample size, and the required minimum of 90 players in each position.

## Procedure

**Figure 1** shows a simplified graphic of our four-stage workflow process. Each of the steps is described in detail below.

### Recruitment

We identified U-team squads that played in the year range 2005 to 2017. This recruitment process for our study was primarily done via Transfermarkt (TM; www.transfermarkt.com), a website which provides extensive football-related information and statistics. We searched the site for the respective team categories (e.g., "Germany U17") and selected the squad lists for the appropriate years. The TM website did not have squad information for every cohort in every U-team, especially for teams in the Scandinavian countries. We therefore searched for data for nations' U-team appearances on national football federation websites to find supplementary squad information. In the rare instances in which the TM website and/or federation websites did not include useful squad lists for our years of interest, we used a third website (www.besoccer.com) to search for U-team appearances and squad information.

After finding information about the U-team players, we then searched for players who had represented their nation's senior team but had not made any U-team appearances. This was done using an "Advanced player search" on the TM website, using the appropriate citizenship and birth year of the players. The following alternatives were then selected from the TM website's menu: (a) "Current national team player": (b) "Former (not current) national team player"; and (c) "Retired from national team". This search identified additional players who had not already been included in our initial searches, and these were then added to the study sample. After filtering out players who were born outside our intended age range (1990–1995), we then created an Excel sheet with a list of players and moved to the next stage of collecting player data.

### Data Collection

Individual player information was copied and pasted manually from the TM website's player profiles into our Excel list of recruited players. The comprehensive list of information we retrieved from the TM website was added to our study pre-registration form, and this can be accessed on the Open Science Framework platform (https://osf.io/xd3rf/). For the purposes of

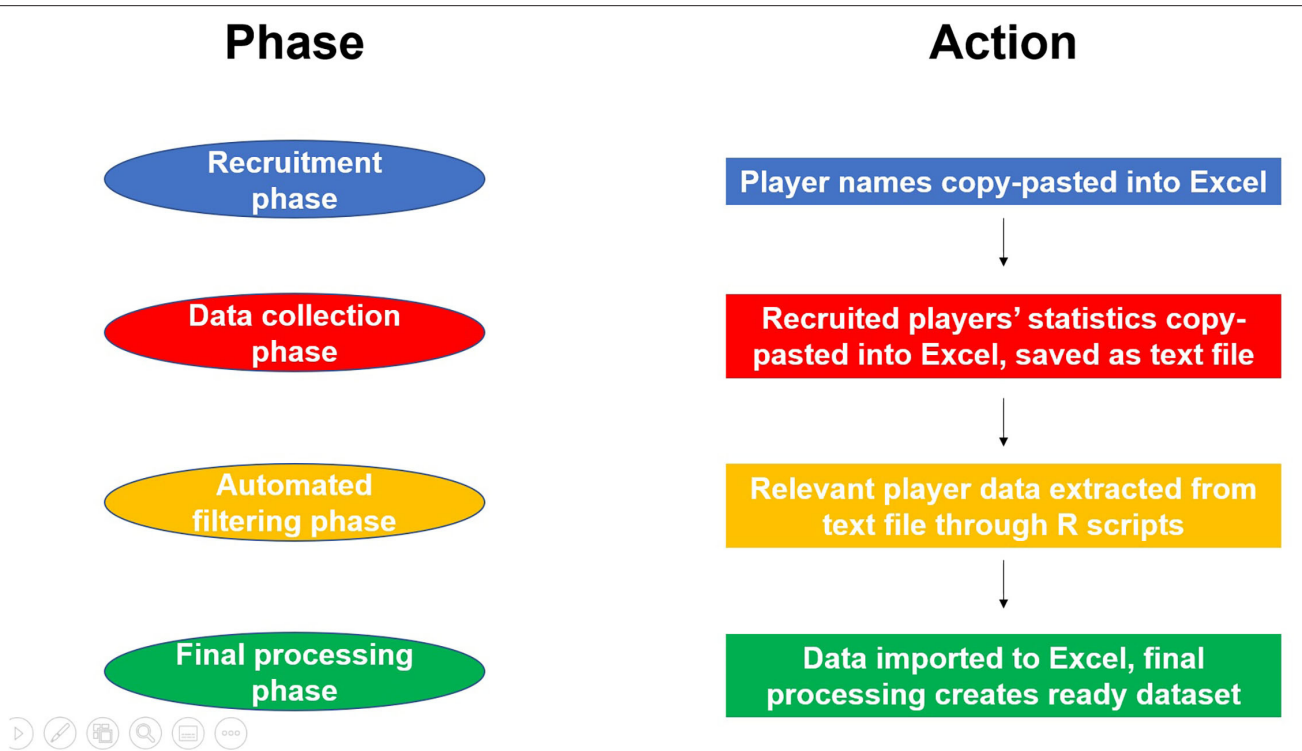


**FIGURE 1 |** A flow chart showing our data work in four different phases, including actions made in each phase.

both our studies, our particular focus was on: (a) basic player characteristics (e.g., birthdate, playing position); (b) appearances for national teams; (c) appearances in the Champions League, the Europa League, as well as top tiers in the 15 highest-ranked nations on the UEFA country coefficients list for 2020/2021.

We were unable to find a TM profile for 27 of the study's recruited players. In these instances, we searched for information about the players via Google and several online football databases (such as www.altomfotball.no, and www.playmakerstats.com). The results of these searches confirmed our assumption that these players had likely never played at the highest levels of football or in any of the top European leagues. While searching for these players' names online, we found evidence that they were within the appropriate age range. We felt certain therefore (beyond a reasonable doubt) that these players had gained international U-team level experience but lacked experience in senior professional football, and that they should be included in our analyses.

Information from player profiles on the respective football federation web pages were also copied into our Excel sheets, so that official national team statistics were included for each player.

## Automated Data Filtering

The raw data we gathered from the TM profiles and from the federation web sites were saved as CSV text files and run through scripts in the statistical program R. One script was used per nation, and the code can be found at the GitHub platform: https://github.com/henrher/Youth-and-senior-success-in-soccer/find/main. The data set and a detailed description of our procedure are also publicly available, at the OSF website: https://osf.io/xd3rf/.

## Final Data Processing

After running the initial script on the raw data, some manual corrections were needed. Our scripts, for example, were unable to retrieve player appearances in the correct way for all players, especially in particular leagues (e.g., the Portuguese top tier, which had recently changed its name). Several duplicate records had to be removed, and we also removed players who: (a) had appeared in games for more than one nation during their career, according to the TM website; and (b) had 0 appearances for the national teams of interest (even though they had been drafted), according to their federation website profiles. Most of the changes to the raw data set were implemented manually in Excel. For certain issues, we ran the raw data through modified scripts in R to retrieve the information we needed. Instructions for how to collect data using our approach can also be found at the OSF website: https://osf.io/xd3rf/.

After this data processing, the total sample of 1,482 players were relatively well distributed across the selected nations and playing positions (see **Table 2** below). A total of 716 players were selected from the Scandinavian countries, and 766 were from the Top nations. The process of categorizing footballers' playing positions–in other words, of deciding which positions could be put under appropriate "umbrella terms" –can be done in several different ways. In our study, we used the same playing position categories described by Kalén et al. (2019). To clarify

**TABLE 2 |** The nationalities and playing positions included in our study.

| Nations | Playing positions |
|---|---|
| Denmark ($n = 238$) | Goalkeeper (Goalkeeper; $n = 152$) |
| Norway ($n = 250$) | Center-back (Center-back; $n = 244$) |
| Sweden ($n = 228$) | Full-back (Left-back, Right-back; $n = 252$) |
| Belgium ($n = 243$) | Central midfield (Central midfield, Defensive midfield, Attacking midfield, Left midfield, Right midfield; $n = 402$) |
| Germany ($n = 301$) | Winger (Left winger, Right winger; $n = 157$) |
| Portugal ($n = 222$) | Striker (Center-forward, Second striker; $n = 191$) |

and document how we operationalized these playing positions, we have included a parenthesized list showing which original playing positions (as listed on the TM profiles, under players' "Main position") were used when deciding on our final position categorizations. Eighty four players were not listed with a specific playing position on TM. These players were included in the analyses as part of their own (unspecified) positional category, but we decided not to focus on or report any effects involving this category in our Results because our focus was on the specified position categories listed in the **Table 2**.

## Data Analysis

For our main analyses of the links between the various Super Elite and U-team variables, we planned to apply a variety of standard regression models. However, it was evident that our data did not meet many of the common assumptions associated with such statistical approaches, and that additional measures would be required.

The first issue became evident when we conducted a binary logistic regression analysis to test Hypothesis 1b (namely, the effect of numerical predictors (U-team appearances), along with fixed factors (nationality and playing position), on athletes' Super Elite status). This model's results were difficult to interpret for two reasons. First, the calculated Hosmer-Lemeshow test value was highly significant ($p < 0.001$), indicating that there was a poor fit between the model we were using and our data. Second, the odds ratio values [Exp(B)] were less intuitive when they were based on continuous predictor variables, as opposed to categorical predictor variables (as used in our test of Hypothesis 1a). We therefore recoded our continuous predictor variables into a nominal variable with limited categories. Specifically, we labeled players according to the following classification for each U-team: (a) Category 0: 0 games; Category 1: 1–5 games; Category 2: 6–10 games; Category 3: 11 games or more. Doing so allowed us to run a logistic regression analysis without violating the Hosmer-Lemeshow test assumptions. This variable coding was therefore used when testing our numerical U-team variables as predictors of Super Elite status.

In our subsample analysis, with numerical variables only (i.e., U-team appearances as predictors of Super Elite appearances), the data appeared to be non-normally distributed. Specifically, *heteroscedasticity* was indicated by a scatterplot and confirmed by statistical tests of this phenomenon in IBM SPSS Statistics v27 (e.g., White's Test, $p < 0.001$). We therefore decided not to use regular multiple regression analysis, and substituted this method instead with general linear models using *robust standard errors* (Hayes and Cai, 2007) when testing the effect of U-team participation on Super Elite appearances.

**TABLE 3 |** U-team status effects on Super Elite status.

| x | B | *SE* | Sig. | Exp(B) | Lower CI* |
|---|---|---|---|---|---|
| U17 | 0.084 | 0.287 | 0.771 | 1.087 | 0.619 |
| U19 | 1.023 | 0.313 | 0.001 | 2.781 | 1.506 |
| U21 | 2.417 | 0.281 | <0.001 | 11.212 | 6.466 |

*95% confidence interval for Exp(B), lower limit.

An Alpha value of 0.01 was our cut-off point for statistically significant effects. We used partial eta squared ($\eta p^2$) as our measure of effect sizes in general linear models, and we considered.01, 0.06 and 0.14 as values indicating small, medium and large effects, respectively (Richardson, 2010). All statistical analyses were conducted using the IBM SPSS Statistics v27 software.

# RESULTS

## Part 1: What Predicts a Player's Super Elite Status?

We conducted a logistic regression analysis of the players' U-team status (whether a player had represented a U17, U19, or U21 team, respectively), as well as fixed factors (national cluster and playing position), as the independent variables. Interactions between the U-team predictors and fixed factors were also considered in the regression model. The full model was found to be statistically significant, $\chi^2$ ($df = 30$, $n = 1{,}482$) $= 542.029$, $p < 0.001$. This suggested that the model allowed us to distinguish between players with, and without, Super Elite football experience. The model explained between 29.8 and 41.6% of players' Super Elite variance, measured by a Cox and Snell R square value and Nagelkerke R Squared value respectively. 79.8% of cases were found to be correctly classified. **Table 3** provides an overview of the U-team variables' effects.

U19 and U21 status were the only significant predictors of players' later Super Elite status. However, the effects of these two predictors were of different orders of magnitude. The odds ratio values [Exp(B)] provided useful indicators of the probability of a player achieving Super Elite experience when he went from Category 0 (having not played for the given U-team) to Category 1 (having played for the given U-team) in these dichotomous U-team variables. A player was therefore 2.78 times more likely to obtain Super Elite level experience if he had represented his country at the U19 level than if he had not. If a player had represented his U21 side, he was then 11.21 times more likely to have Super Elite experience compared to those players who had not.

U19 status showed a significant interaction with nation cluster ($p = 0.006$). We therefore ran one regression model per cluster, using the dichotomous U-team predictors as independent

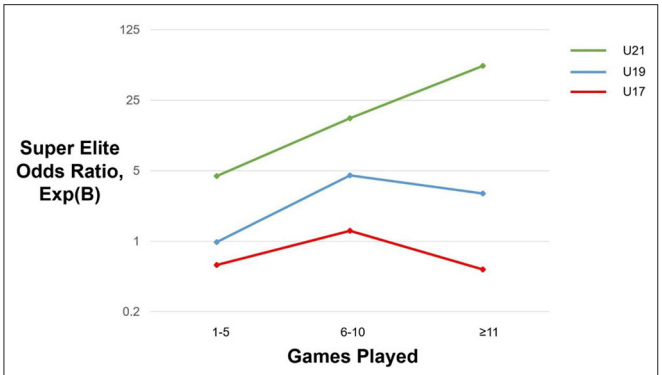


**FIGURE 2 |** Likelihood of achieving Super Elite status as a function of the number of games for various U-teams. Please note that the values on the Y-axis are nonlinear. We have used a logarithmic scale (of increasing magnitude) to reveal the nuances at the lower end of the graph and to capture the trajectory of the U21 odds ratio values toward the higher end of the spectrum.

variables. Our findings suggested that U19 status is a significant predictor of Super Elite status in the Top nations [Exp(B) = 2.244, $p < 0.001$], but not in Scandinavia [Exp(B) = 1.009, $p = 0.969$]. In other words, U21 status was a significant predictor throughout the sample, while U19 status depended on the particular nation cluster when predicting who would reach Super Elite status. It is, however, worth noting that the Hosmer-Lemeshow values we calculated were significant ($p < 0.001$) for both these follow-up regression models, and that caution is generally needed when interpreting analyses on sub-samples. Playing position was found not to be significantly related to Super Elite status as a main effect or in interaction with the predictors.

Next, we conducted a binary logistic regression analysis using players' U-team appearances as numerical predictors along with the fixed factors as independent variables. Interactions between the main predictors and fixed factors were again investigated. As discussed in the Methods (Data Analysis) section of this paper, each player's number of appearances was coded into four categories (0, 1–5, 6–10, 11 or more, respectively) in each U-team, for methodological reasons. The full model was found to be statistically significant, $\chi^2$ ($df = 75$, $n = 1{,}482$) = 672.661, $p < 0.001$. The respective Cox and Snell R square value and Nagelkerke R Squared value suggested that the model explained between 36.5% and 50.9% of variance in Super Elite status in our sample. 82.2% of cases were correctly classified. Of the main predictors, the U19 ($p < 0.001$) and U21 ($p < 0.001$) variables, and not U17 appearances ($p = 0.191$), were found to have a significant impact overall on a player's Super Elite status. When exploring categories within the U-teams, interesting nuances were observed. **Figure 2** visualizes changes in the odds ratio [Exp(B)] when players moved from Category 0 to 1, from Category 1 to 2, and from Category 2 to 3 in the various U-teams. Any value above the line drawn where the Exp(B) value equals 1 indicates the likelihood of a player reaching the Super Elite level would *increase*, while any Exp(B) value between 0 and 1 (i.e., below the line) indicates that the probability of a player reaching the Super Elite level would *decrease* when entering a given category.

As shown in the graph, the U19 pattern shows an increase in the likelihood of players attaining Super Elite status when they move from Category 1 (1–5 games) to Category 2 (6–10 games). This likelihood decreases again when players enter Category 3. Only the second U19 category had a significant ability to predict a player's Super Elite status (Exp(B) = 4.484, $p < 0.001$). The visual pattern was similar for players in the U17 categories, albeit with odds ratio values that were lower–some even below 1–suggesting negative predictive values. No statistical significance was found for any of the U17 categories. The development within the U21 variable, on the other hand, more closely resembled exponential growth, as players moved into Category 1 [Exp(B) = 4.425, $p < 0.001$], Category 2 [Exp(B) = 16.629, $p < 0.001$], and Category 3 [Exp(B) = 54.664, $p < 0.001$].

The abovementioned U19, Category 2 (6–10 games) showed a significant interaction with nation cluster (B = −1.151, $p = 0.10$, Exp(B) = 0.316). This finding was intriguing because Category 2 was the only significant U19 category found in the main effects. We therefore ran one regression model per nation cluster, using the U-team predictors as independent variables. The results echoed our previous sub-sample analyses. Specifically, only the U21 category, at all category levels, was found to be a significant predictor of whether Scandinavian footballers achieved Super Elite status. On the other hand, significant effects of appearances at the U19 level [all categories except for Category 1 (1–5 games)] and U21 (all categories) were found in the model of Top nations. Hosmer-Lemeshow values were significant at the conventional level ($p < 0.05$) for both these follow-up regression models.

Additionally, the U19 Category 2 (6–10 games) showed a significant interaction with the goalkeeper position (B = −2.589, $p = 0.007$, Exp(B) = 0.075). This position was also noticeable because of interaction trends found with other U-team categories that would have been significant at a conventional level of significance ($p < 0.05$). Hence, we decided to run a regression model using only the 152 goalkeepers in this sample, using their U-team appearances as predictors. Although this test had a limited sample size and should be interpreted with caution, the results suggested that only U21 appearances (all categories) were significant at the level of $p < 0.01$ and had a positive increase in predictive value in each category. In summary, the number of U19 appearances did not significantly predict Super Elite status among Scandinavian players and among goalkeepers.

Finally, we explored the effect of different U-team career types on athletes' Super Elite status. We divided our player sample into all possible national team career combinations using eight categories (see **Table 4** below). To test the predictive value of each career type, a binary logistic regression model was employed. Descriptive statistics showed that the most common career type of the selected players was "U17 only". This category was therefore used as a reference group, and this enabled us to test the effects of increasing career length and/or latency by comparing all other career types with those who only had U17 experience.

**TABLE 4 |** U-team types of careers in relation to Super Elite status.

| Career Type | *N* | B | *SE* | Sig. | Exp(B) | Lower CI* |
|---|---|---|---|---|---|---|
| U17+U19+U21 | 293 | 3.860 | 0.286 | <0.001 | 47.464 | 27.096 |
| U19+U21 | 151 | 3.600 | 0.307 | <0.001 | 36.600 | 20.043 |
| U21-only | 129 | 3.030 | 0.311 | <0.001 | 20.693 | 11.254 |
| U17+U21 | 30 | 3.014 | 0.446 | <0.001 | 20.375 | 8.501 |
| U17+U19 | 276 | 1.052 | 0.315 | 0.001 | 2.863 | 1.544 |
| U19-only | 236 | 0.881 | 0.332 | 0.008 | 2.414 | 1.259 |
| Senior-only | 25 | 24.217 | 8,038.594 | 0.998 | 3.292E+10 | <0.001 |
| U17-only | 342 | N/A | N/A | N/A | N/A | N/A |

*95% confidence interval for Exp(B), lower limit.

The model was statistically significant, $\chi^2$ ($df = 7$, $n = 1{,}482$) = 599.336, $p < 0.001$. This suggested that the model was able to distinguish between players with, and without, Super Elite football experience, based on their career type. The model explained between 33.3 and 46.4% of variance in the players' Super Elite status, as measured by a calculated Cox and Snell R square residual and a Nagelkerke R Squared value respectively. 80.0% of our cases were found to be correctly classified.

All the categories were statistically significant except for the player group with senior national team experience only ($n = 25$). The table below provides an overview of the career types in relation to players' Super Elite status. The table is sorted in descending order, with the significant career types and the largest odds ratio values on top.

The calculated odds ratio values indicated that there were substantial differences between the player career types that involved U21 participation on one hand, and those that had no U21 participation on the other. Representation at the U21 level, especially in combination with selection to an U19 team or both the other U-teams, was found to be indicative of players having a dramatically increased chance of achieving Super Elite status.

## Follow-Up Analysis: Does Earlier U-Team Status Predict Later U-Team Status?

Our primary concern in this study was the link between U-team participation and a player's Super Elite participation. However, since a U21 status, and to some extent a U19 status, appeared to significantly predict a player's later Super Elite status, we decided to conduct binary logistic regression analyses to explore the relationships between the categorical U-team variables. Our first regression model tested whether U21 status could be predicted by a player's U17 or U19 status. Our results suggested that a player's U17 status was a negative and significant predictor [Exp(B) =0.515, $p$ <0.001] while his U19 status was a positive and significant predictor [Exp(B) = 1.885, $p$ <0.001] of U21 experience. U17 status was also a negative and significant predictor of U19 status [Exp(B) = 0.609, $p$ <0.001] in our subsequent regression model. In summary, players in our sample who had U17 experience were less likely to gain experience at the U19 and U21 level, compared to those players with no U17 experience. Participation in one or more U19 games, on the other hand, was a significant predictor of participation in one or more U21 games. The Hosmer-Lemeshow test value for our first binary regression model was significant, but the significance and direction of the relationships between U-teams were confirmed by follow-up Chi square tests.

## Part 2: What Predicts the Number of Appearances at the Super Elite Level?

Only players with Super Elite experience ($n = 482$) were included in the analyses targeting this question. We first tested the predictive ability of U-team status in relation to Super Elite appearances. A univariate regression model with robust standard errors [HC3 method; see Long and Ervin, 2000] was employed. The adjusted R squared value we calculated was 0.017, which suggested that our model explained 1.7% of the variance in the number of Super Elite appearances players had. The effect of their U17 status (B = 2.922, $p = 0.322$, $\eta p^2 = 0.002$) and U19 status (B = −3.728, $p = 0.267$, $\eta p^2 = 0.003$) was found not to be significant. Conversely, a significant main effect was found for U21 status (B = −10.204, $p = 0.003$, $\eta p^2 = 0.019$).

Next, a univariate regression model with robust standard errors (HC3 method) was conducted to test the effects of U-team appearances on Super Elite appearances. The calculated adjusted R squared value was .032, which suggested that our model explained 3.2% of variance in the number of Super Elite appearances players achieved. Effects of U17 appearances (B = 0.620, $p = 0.207$, $\eta p^2 = 0.003$) and U19 appearances (B = 0.048, $p = 0.878$, $\eta p^2 < 0.001$) were not significant, while U21 appearances (B = 0.506, $p = 0.003$, $\eta p^2 = 0.018$) was a significant predictor of Super Elite appearances.

Overall, our two subsample analyses yielded highly similar results, suggesting small yet significant and positive effects of U21 participation on Super Elite appearances.

# DISCUSSION

Our study was designed to determine whether youth international experience was a predictor of player participation at the highest level of football, which we termed the Super Elite level. In Study 1, we used factor analysis to define this highest level of participation as a Super Elite participation factor–namely, player participation in senior international squads, the Champions League, and/or the Europa League. In Study 2, we tested hypotheses concerning whether player participation in U17, U19, and U21 teams were associated with Super Elite status across nationalities and playing positions. We also tested the predictive ability of U-teams in relation to Super-Elite appearances, once players had reached Super Elite status. Overall, our study extends the existing literature that suggests that performance in youth categories is a limited indicator of senior success.

Our first study contributes to the challenge of defining elite performance levels in football (Swann et al., 2015). The proposed Super Elite factor provided us with a clear outcome measure, and it may be used or built upon in future studies on higher levels of elite football. In our second study, the combinations of categorical and continuous variables further enabled us to draw nuanced conclusions. We were able to explain far more variance

in Super Elite status than we were able to predict the number of games at the highest level. Specifically, our models that tested who reached the Super Elite category explained up to 50.9% of variance, while models predicting the number of Super Elite games explained only 3.2% of variance at the most. This speaks to the difficulty of predicting which young players will end up with numerous appearances at the top level of football (Güllich and Emrich, 2012).

We found several variables that significantly predicted players' status (i.e., one or more games) in Super Elite football: (a) U21 status and U21 appearances (number of games); (b) U19 status as long as the players were from the Top nations, and U19 appearances if the players were from the Top nations or played outfield positions (i.e., not goalkeepers); and (c) all careers involving a U-team, except for those with only U17 experience – particularly 'late' careers (i.e., involving U21 experience) and especially 'late and long' careers (i.e., experience from U21 combined with one or more U-teams).

Unsurprisingly, the U21 variables were found to be the most significant, consistent, and substantial individual predictors of Super Elite status, and the only significant predictor of Super Elite appearances. This suggests that U21 participation is an indicator of senior success in football. In contrast, U17 participation showed no significant relationship to Super Elite participation. This is a noteworthy finding given that U17 selection is regarded as prestigious in football and is seen as important by football federations and the media alike. As for U19 participation, its role as a predictor may be summarized as "it depends": the roles of U19 status and appearances appeared to depend on player characteristics, namely their nationality and their playing position, and this we will discuss later. Overall, our results echo previous findings reported by Bjørndal et al. (2018) and Schroepf and Lames (2018), which suggest that indicators of senior sporting success appear later rather than earlier in athletes' careers.

Inspired by the approach of Schroepf and Lames (2018), we explored the predictive value of different U-team career types. When closely examining the descriptive statistics, two career types were found to be uncommon in our sample of 1482 players. First, the combination of U17 and U21 participation, without any U19 participation in-between, was rare ($n = 30$). This finding was similar to those reported in past studies in football that reported substantial player turnover and few "comebacks" after de-selection from U-teams (Güllich, 2014; Schroepf and Lames, 2018). The second small and uncommon group consisted of players who had no U-team appearances, and only senior national team experience ($n = 25$). This finding was similar to those reported by Bjørndal et al. (2018) in the context of handball.

Nonetheless, our study showed that it is possible for players to reach the Super Elite level even if they have had no appearances in youth international teams. Schroepf and Lames (2018) reported that all 37 German senior national team players in their study, born between 1987 and 1994, had represented a U-team. Unexpectedly, in our study we were able to identify six German players who had no international youth experience (for any U-team, ranging from U15 to U23), but who had represented the German senior national team (Jonas Hector, André Hahn, Diego Demme, Marcel Halstenberg, Mark Uth, and Robin Gosens–all born in the period 1990–1994). Why these players were not included in the Schroepf and Lames (2018) analyses is still unclear, even after a thorough reading of their paper. This underlines the imperative of openness and clarity in study reporting. However, our overall findings were similar to those of Schroepf and Lames (2018) who observed that later selection and longer careers in youth international teams are indicators of successful senior football careers, although in their study they included all U-teams from U15 through U21 while we focused on the U17, U19, and U21 categories only.

To our knowledge, ours is the first study of its kind to include playing position as a variable, and our results need to be tested and replicated before generalizations can be made with confidence. In terms of effect sizes, the interactions we found between U-team predictors and positions were nuanced and small. Nonetheless, we found in our sample that one certain predictor effect disappeared when analyzing goalkeepers only ($n = 152$). Specifically, U19 appearances did not predict the later Super Elite status for goalkeepers. One possible reason for this is that the U-team selection of goalkeepers may strongly reward growth and maturation, due to the anthropometric demands of the position (Deprez et al., 2015; Brustio et al., 2018), rather than simply the skills that help players gain a successful senior career. Further studies are needed to replicate and elaborate on the relationship between playing positions and career transitions in team sports.

Our findings suggest that the link between U-team participation and senior elite participation is stronger in top-ranked nations compared to the Scandinavian countries. When analyzing our Scandinavian recruited players only, we found that U19 participation–categorically and numerically – was unable to significantly predict who will end up in Super Elite football, while the opposite was true when analyzing players from Belgium, Germany, and Portugal. This may be due to the differences between how sport, in general, and talent identification and development in particular, are organized across national contexts. For example, in Scandinavian countries, the voluntary-based sport model is characterized by decentralized, egalitarian structure with low levels of professionalization (Ibsen and Seippel, 2010). Compared to most academy-based programmes in other countries, this model represents a clear point of difference (Bjørndal et al., 2015). The less structured and non-commercial Scandinavian model may increase overall sports participation initially, and the length of playing careers eventually, and therefore weaken the association between formal talent identification programmes and senior success (Andersen et al., 2015). In comparison, the elite sport systems of Belgium, Germany and Portugal may inflate the effects of selection mechanisms at an earlier age, compared to the Scandinavian countries, resulting in stronger associations between formal talent identification and development programmes and senior success. Exploring these assumptions further opens an important new line of inquiry for future research.

Despite the strengths of this study, some limitations should be considered before these findings can be generalized across populations. Firstly, our sample consisted of international players only. Hence, the career pathways of successful senior elite players who do not have any competitive experience from youth international teams should be of particular interest in future research. Secondly, we included only U17, U19 and U21 teams as our main predictors for methodological reasons. It is worth noting that some countries, such as Norway, place heavy emphasis on other U-team classifications as well (e.g., U18, U20). It is therefore unclear whether including more teams, as has been done in other studies (Güllich, 2014; Schroepf and Lames, 2018), may lead to different results. However, our aim was to investigate teams that were comparable between nations, and our methodological decision facilitated this purpose.

## CONCLUSION

The study demonstrates that competitive experience gained from youth international teams is a limited predictor of senior success in professional football, and that there were few distinct variations to this across nationalities and playing positions. Participation at the U21 level was the strongest, most consistent predictor of Super Elite level participation. U17 participation was found to be either an insignificant or a negative predictor of subsequent participation in international football. The link between U19 participation and later participation was partly significant, but weaker than participation at the U21 level, and depended on national context and playing position. When looking at the effect of different youth career types on later participation, careers that included U21 international experience were the most substantial predictors of Super Elite careers.

Considering the nonlinear nature of development in sport and how performance before adulthood is strongly influenced by growth and maturation, systematic talent identification is limited at best. Investments in association-based youth talent identification and selection systems in football may not be useful because such participation does not appear to be a strong predictor of later international elite football participation. Our findings indicate that sport governing bodies need to re-consider their strategies for talent identification and development: before players reach adulthood, fewer resources could be spent on helping a limited number of selected players gain competitive international team experience. This may mean, instead, that the limited economic and human resources that are available should be re-allocated to more local activities that promote recruitment, participation, and development at the grassroots level. Doing so could achieve broader benefits without compromising the development of elite sport.

## DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/xd3rf/.

## ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

## AUTHOR CONTRIBUTIONS

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

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2022.875530/full#supplementary-material

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# Corrigendum: Youth International Experience Is a Limited Predictor of Senior Success in Football: The Relationship Between U17, U19, and U21 Experience and Senior Elite Participation Across Nations and Playing Positions

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## A Corrigendum on

**Youth International Experience Is a Limited Predictor of Senior Success in Football: The Relationship Between U17, U19, and U21 Experience and Senior Elite Participation Across Nations and Playing Positions**

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In the published article, there was an error in **Figure 2** as published. In **Figure 2**, we provided the wrong label for the category on the far right of the x-axis. Specifically, the label said "11–15." The correct label is "≥11." The corrected **Figure 2** and its caption appear below.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

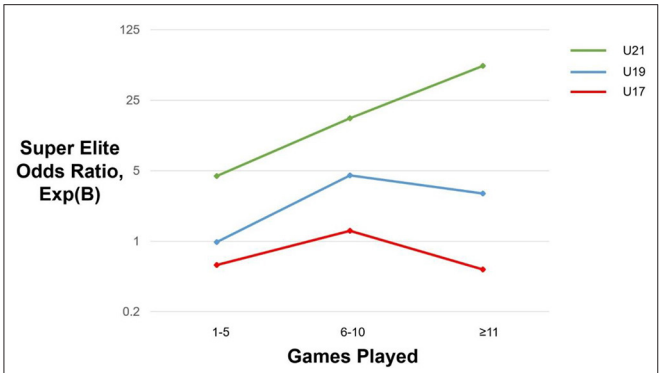


**FIGURE 2 |** Likelihood of achieving Super Elite status as a function of the number of games for various U-teams. Please note that the values on the Y-axis are nonlinear. We have used a logarithmic scale (of increasing magnitude) to reveal the nuances at the lower end of the graph and to capture the trajectory of the U21 odds ratio values toward the higher end of the spectrum.

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# An embodied and ecological approach to skill acquisition in racecar driving

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Racecar driving is a fast-paced sport that presents the driver-athlete with many perception-action coupling and decision-making challenges. One question that arises is how racecar drivers deal with the influx of perceptual information and manage to perform successfully in such high speeds and, as a result, very limited time to make decisions and act upon them. In this perspective paper, I suggest that the ecological approach is one theoretical framework that can help researchers understand how skill is acquired in racecar driving. I also suggest that an embodied perception of affordances can provide a good basis for research in the field. Specifically, it is an extended embodied cognition that includes not only the driver's mind and body, but the car itself. In a sense, the driver and the car are embodied into one unit and any perception of affordances should be based on this unit. This paper will also discuss the constraints during a race, the affordances the race driver must perceive and how they change over the course of a race, and how researchers can use a racecar driving paradigm to study human perception and action from an embodied and an ecological approach. Specifically, because the driver is seated, measuring EEG and eye movements is relatively simple and can provide additional information on drivers' visual perception of affordances, and their ability to act upon them.

KEYWORDS

racecar driving, ecological psychology, embodied cognition, motor learning, affordances

## 1 Introduction

Racecar driving is an inherently fast-paced and dynamic sport that requires drivers to make decision and act upon them under extreme time constraints. Driver-athletes are required to remain attentive for long durations under many physiological stressors that include, for example, high gravitational (g) forces, heat stress, and cardiovascular stress (1). Under such prolonged physiological stress, drivers must perform complex perceptual-motor tasks required to successfully maneuver the racecar around the track as fast as possible. Understanding how racecar drivers can perform under such conditions is a challenge and the literature on racecar driving is relatively limited. As racecar driving becomes more popular (e.g., TV audience for Formula One races in 2021 was 1.55 billion – a 4% increase from 2020, and 108.7 million for the last race of the season – a 29% increase from the same race in 2020 (2)), it may prove useful to study how racing skills are acquired as more novice drivers will potentially join motorsports in the near future.

I suggest that an ecological perspective (3) can guide research on skill acquisition and performance in racecar driving. From this perspective the individual (in our case a race driver) cannot be separated from the environment (4), and thus research should focus on the individual-environment (driver-racetrack) system. A key concept of the ecological approach is that of affordances – opportunities for action based on the interaction

between the animal and the environment (3). For example, for an adult human a chair may afford sitting – that is, the functional fit between the person and the chair creates the affordance of sit-ability. The perception of such affordances underlies the concept of affordance-based control (5). Affordance-based control suggests that the main purpose of perception is to allow us to see the world in terms of what we can do in it, and that successful performance relies on our ability to perceive possibilities for action (5). Indeed, from an ecological perspective, the environment is directly perceived in terms of affordances that provide different opportunities or invitations for actions that guide behavior (6). In this respect, skill learning is seen as the establishment of an adaptive, functional fit between an individual and its environment (7). Based on these key concepts of the ecological perspective, racecar drivers cannot be studied outside the racecar and the environment of the racetrack. This implies that we should study performance in real-world scenarios or design tasks and environments that simulate these scenarios, which aligns with Brunswik's (8) idea of representative design for experiments (see also (9), for sport-related representative task design).

Moreover, racecar drivers' performance will be affected by their ability to perceive relevant affordances such as the possibility or invitation to overtake another car (i.e., overtake-ability affordance), and the potential to drive through a turn at the highest speed possible (i.e., turn-ability affordance). One can also argue that such affordances are related to the constraints imposed on the driver. First characterized by Newell (10), constraints can be divided into three categories: (1) Organismic/Individual constraints (e.g., height, reaction time, motivation); (2) Task constraints (e.g., goal of task, rules of competition); and (3) Environmental constraints (e.g., visibility, outside temperature). Multiple constraints from these three categories interact over varying timescales, influencing the development of skill (11).

In addition, I argue that the driver's perception-action coupling cannot be separated from the car itself, and thus the organism of interest is the driver-car unit. This statement relates to the concept of embodied cognition which suggests that we should study the mind in its relationship to the organism's physical body that interacts with the world (12), or in race driving, understand the mind in its relationship to a driver-racecar unit. More recently, Raab and Araújo (13) suggested that to understand the relationship between individuals and their environment, an embodied cognition perspective is required. The embodied cognition perspective is influenced, at least in part, by the works of late 19th and early to mid-20th century philosophers such as John Dewey (see for example (14)) and Maurice Merleau-Ponty (15). Dewey (14) suggested that "*Every "mind' that we are empirically acquainted with is found in connection with some organized body. Every such body exists in a natural medium to which it sustains some adaptive connection…*" (*p*.277). Merleau-Ponty (15) wrote that: "*…in so far as my body is, not a collection of adjacent organs, but a synergic system, all the functions of which are exercised and linked together in the general action of being in the world…*" (*p*. 272). Embodied cognition suggests that the body contributes to cognition and influences our perception, and that performance emerges from coupling of the nervous system, the body, and the environment (16). In this respect, Mace (17) suggested that to understand perception we should "Ask not what's inside your head, but what your head's inside of" (*p*. 43). This concept contrasts with the more standard cognitive approach suggesting that our brain is locked inside our head, separated from the environment, and receives impoverished environmental information. Based on this poor sensory input and internal mental representations of the world, the brain is required to provide behavioral solutions based on its best guess of what is currently required (18).

It is important to note that several studies have examined the ecological approach to driving (e.g., (19–21)) and one may ask why racecar driving would be any different as it may appear that race driving is *just like regular driving but faster*. I argue that there are fundamental differences between regular, passenger car driving and racecar driving. Indeed, Lappi and Dove (22) suggested that when seeing elite athletes perform, we know that we are not capable of doing what they do. However, our feeling on racecar diving may be different. Lappi and Dove (22) add that: "*…for many people the brain will go Well, you know, I could probably do that – they"re just sitting there and turning the wheel, what"s the big deal? When the casual observer looks at a racing car at speed, the natural thing is to relate it to your everyday experience: More of the same, just at a higher level of speed (and risk), the brain says. The tiny cues that tell how the vehicle is being balanced, how it is manipulated to extract maximum speed, may be too subtle to register to the non-expert eye.*" (*p*. 20–21). Indeed, like in many other sporting activities, racecar driving requires intricate perceptual-motor skills that are mostly unattainable by those who do not practice it. Therefore, despite the available literature on driving passenger cars, examining racecar driving is an endeavor worthy of independent effort.

The ecological perspective and the embodied cognition perspective are both important for the understanding of human performance as cognition is both embodied and embedded (in the environment) (23). Therefore, the purpose of the current perspective paper is to show how embodied cognition and an ecological perspective can explain skill acquisition in racecar driving. First, I will briefly discuss the embodied cognition of the racecar driver. Second, I will discuss the main constraints in racecar driving. Third, I will discuss the possible affordances in race driving. Finally, I will provide avenues for future research based on embodiment and on the ecological approach.

## 2 Embodied cognition in racecar driving

Wilson (12) discussed six views of embodied cognition, some of which are particularly relevant to racecar driving. One view is that cognitive activity is situated in a real-world environment, involves perceiving environmental information, and executing motor activities accordingly (i.e., perception-action coupling). Driving is a situated cognitive activity, made for action (i.e.,

driving the car successfully), and best understood when examined in real-world scenarios. However, conducting research in a real-world racing scenario maybe difficult and impractical. In this respect, representative, high-fidelity racecar simulators – specifically, simulators with high action fidelity in which performance is similar among the simulator and the simulated system (24) – can be of great benefit for the study of race drivers. Simulators are unlikely to completely simulate the real environment and transfer of learning is a good measure of action fidelity (24). In the case of racecar driving, such action fidelity will mean, for example, that lap time in the simulator may transfer to the real track.

A second view suggests that cognitive activity occurs often under time pressure. This is particularly relevant to the fast-paced sport of race driving. For example, racecar drivers have very little time to decide, based on the continually changing information available (e.g., distance to the optimal braking point before a turn, speed, position of cars on track), whether to overtake another car before they need to start braking as they approach a turn. If drivers miscalculate, they may brake too late and approach the turn too fast. This may lead to wheel lockups[1] that will cause faster tire degradation, or to completely missing the turn and losing valuable lap time. In the worst-case scenarios, such wrong decisions can lead to crashing into the other car or into the barriers.

A third view of embodied cognition is that the environment can be considered as a part of a cognitive system. Wilson (12) explains that: "*The forces that drive cognitive activity do not reside solely inside the head of the individual, but instead are distributed across the individual and the situation as they interact.*" (*p.* 630). This means that the cognitive system encompass the mind and the physical body, but also objects in the near environment (12). In racecar driving, I suggest that embodied cognition includes, at the very least, the mind of the race driver, his/her physical body, and the racecar itself. This will be important when we try to understand race drivers' constraints and perception of affordances on the racetrack. Such affordances relate to a driver-racecar unit, and not only to the physical body of the driver. In regular driving, Dant (25) discussed in depth the importance of examining the driver-car unit and "The Embodied Driver-car" (*p.* 71). I suggest that, similarly, we should examine in depth the driver-racecar unit.

## 3 Constraints in racecar driving

**Figure 1** presents some of the constraints racecar drivers encounter based on the Newell's (10) categories. Environmental constraints include outside temperature and humidity, the temperature of the tarmac, wind conditions, etc. Some functional constraints of the organism include reaction time, visual perception, and attentional capabilities. Task constraints include the rules of the race (e.g., how much space a driver must leave for an opponent driver on the tarmac, speed limits in pit lane).

However, when it comes to the properties of the car, we need to make a distinction between properties that present task constraints and properties that cannot be separated from the driver and represent the constraints of the driver-racecar unit (and thus relate to the organism). Newell (10) suggested that machines (such as cars or bicycles) can be considered as task constraints. Such task constraints are related to the way the driver operates the car and can include the responsiveness of the brake pedal and the location of the various functional buttons on the steering wheel. However, other properties of the car cannot be separated from the driver, especially from an embodied approach. Constraints of this driver-racecar unit (organism) include the size of the car, acceleration properties, tire grip, weight, etc. Some of those constraints are fixed (e.g., size of car), and some are dynamic (e.g., weight of car reduced from lap to lap as fuel is being consumed, tire grip reduced from lap to lap as tires degrade). The constraints of this driver-racecar unit are crucial for understanding how drivers perceive affordances and learn to act upon them.

## 4 Affordances in racecar driving

Perhaps the most intuitive affordance that racecar drivers must perceive is overtake-ability. Drivers must be able to recognize a gap and decide whether they have the space (spatial constraint) and the time (temporal constraint) to overtake another car. Several studies have examined drivers' perceptions of affordances (20, 21, 26). However, when driving passenger cars safely according to the rules, there is little or no temporal constraints. Drivers overtake in open roads when there is plenty of time to complete the overtaking maneuver. Racecar drivers face a more complex problem. The driver-racecar unit must pass through a gap in a very limited amount of time. This added temporal constraint creates a great challenge for perceiving the overtake-ability affordance in racecar driving. Indeed, Fajen et al. (27) suggested that in fast-paced dynamic sports affordances appear and disappear in an instant and that to succeed, "*athletes must be acutely aware of the ever-changing opportunities for action afforded by the situation*" (*p.* 80). For the racecar driver, an opportunity to overtake may be available one moment only to disappear in the next one.

Another factor that may affect the perception of overtake-ability is the environment that creates and surrounds the gap the drivers face. Hackney et al. (28), for example, showed that individuals behave differently when passing through an aperture made of inanimate objects or of other individuals. When the obstacles that create an aperture are other individuals (rather than inanimate objects), the critical size of the aperture that causes participants to rotate their shoulders (rather than walk

[1]Wheel lockup means that the wheel stops rotating while the car is still moving, causing the tire to scrape on the tarmac. This can happen when the race driver brakes too hard and can lead to faster tire degradation – specifically in one spot on the tire.

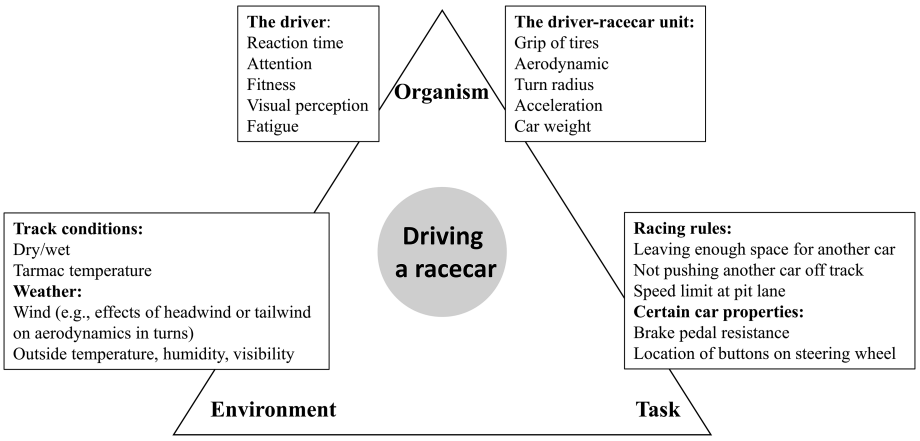


FIGURE 1
The constraints in racecar driving.

straight through) is larger, possibly to account for individuals' need for personal space from others. This finding shows that it is not only the size of the gap that matters, but that the objects or organisms that create the gap matter as well. We can expand on this finding and ask for example: (1) do novice drivers perceive overtake-ability only when a larger gap is available (e.g., because they are more careful to avoid the objects that create the gap)?, and (2) does the size, distance, material, of the objects that creates the gap between the opponent car and the edge of the track matter? For example, do drivers perceive overtake-ability opportunities more easily when there is space between the edge of the track and the barrier compared with a condition in which the barrier is constructed right on the edge of the track (like in many street circuits).

Another question in this context is how accurately individuals assess the limits of the vehicles they operate. This is relevant for driving passenger cars as well. Schwebel and Yocom (21) (Study 1), reported only modest accuracy in drivers' perception of their car's affordances. In contrast, Morice et al. (20) found that drivers are sensitive to their car's limits and select when to overtake by perceiving an overtake-ability affordance. However, in regular driving conditions, the time constraints when legally overtaking on a straight road are more lenient, and the gaps are relatively large. In racecar driving, the question is how drivers develop the skills to perceive overtake-ability in high speeds, with gap sizes that are many times just enough for the racecar to pass through, and with very limited time before they must brake as they approach an upcoming turn. One possible explanation for the ability of racecar drivers to accomplish such overtaking maneuvers is that they are better at attuning to the relevant environmental information at high speeds. While this may certainly be part of the explanation, racecar driving is fundamentally different than passenger car driving and thus requires specific perceptual-motor capabilities.

In addition, if individuals can learn to accurately assess whether a vehicle they operate pass through a gap, is there a limit to this ability? A car is a relatively small vehicle, but can operators of heavy machinery or passenger airplanes do the same? I suggest that there is a limit for such an embodied machine-operator system. It is unlikely, for example, that a pilot taxiing on a runway can accurately perceive whether the tip of the wing passes through a certain gap. Indeed, airports have strict taxiing rules that prevent the pilot from the necessity to perceive such affordances. So, two relevant questions remain: (1) how racecar drivers learn to accurately assess the driver-racecar unit's overtake-ability under extreme time constraints, and (2) Does the size of the vehicle affect the ability and the time it takes to acquire the skill of accurately assessing the driver-racecar unit's affordances.

Identifying gaps is not the only affordance a racecar driver must perceive. The racing driver needs to maneuver the car as fast as possible around the track and maintain the highest speed possible when engaging a turn, without losing grip. The car's grip and the ability to maintain the highest speed when turning depends on many factors such as the tire type, temperature, and condition, the car's aerodynamic setup, and the weather conditions (i.e., wet tarmac, wind conditions). These variables will decide when drivers break before the turn, and how fast they reach maximum throttle (i.e., how fast can they step on the gas pedal) as they speed out of the turn. Some of those variables are constant (e.g., type of tire until pitting for tire change, tarmac temperature if weather is stable), but other variables change continuously. Specifically, tire grip is gradually reduced as they are degraded from lap to lap and thus the perception of turn-ability must change as well. For example, when engaging a turn, a new set of tires will allow drivers to maintain greater speeds and to be more aggressive on the throttle as they speed out of the turn. After a few laps, these same tires no longer allow these actions. The tires now provide less grip, and drivers must calibrate their perception of turn-ability. Drivers should now accelerate more smoothly, or they will lose grip. This is a great challenge for drivers. On one hand, they want to push the car to the edge of grip to achieve the highest speed as they accelerate from the apex of the turn onto the straight. However, if they

push too hard, they risk losing the car. This balancing act, that must be constantly evaluated as the tires degrade from lap to lap requires the driver to be highly attentive throughout the race to the condition of the car and to perceive the correct affordances accordingly.

Finally, racing drivers also need to defend from other drivers who try to overtake them. In these situations, the defending driver can choose where to position the car on the track so the driver trying to overtake will have a harder time doing so. As Withagen (29) suggested, affordances can be seen not only as possibilities or opportunities for action, but also as invitations for actions. In this respect, defending drivers can "*invite*" drivers that try to overtake them to a specific location on the track by, for example, creating a large inviting gap in one side of the track. The side of the track, for example, that would require the overtaking driver to brake earlier, or to accelerate slower, or to miss the apex, and thus fail in their overtaking attempt. To do so, the defending driver should have an intimate knowledge of the situation by perceiving the relative locations and speeds of their car and the car of the other driver, and then realize how to create an "affordance trap" that invites the overtaking driver to a suboptimal overtaking solution.

# 5 Where do we go from here? research in racecar driving

Racecar driving provides an excellent framework for studying skill acquisition and expert performance (See Lappi (30) for a list of 12 features that make it so). From an embodied an ecological perspective, driving simulators can provide high-fidelity representations of the real-world task. These simulators are relatively cheap and can be incorporated in a virtual reality (VR) environment. Specifically, such simulators can provide a model that considers many of the relevant variables that affect drivability. These variables include, among other things, the type of tires, tire temperature and degradation over time, brake temperature, weather conditions, car weight, etc. In addition, the simulator can provide the driver with haptic feedback through the steering wheel. Taking into account the variables that affect the car's grip and the haptic feedback the driver receives should allow for high action fidelity although it remains to be seen whether performance in the simulator transfers well to the racetrack.

However, it is important to note that the physical exertion and physiological stress related to racecar driving cannot be simulated. Specifically, we cannot simulate the high g-forces that drivers encounter while racing. These g-forces can have negative effects on drivers' attention and fatigue. Therefore, simulator studies should be complemented by real-world racecar driving research. Studies on the actual racetrack can help us understand the relationships between gaze behavior, EEG signals related to perception-action coupling, and driving performance under stressful conditions (e.g., heat stress, high g loads) that cannot be simulated. It has been shown that EEG (e.g., (31)) and eye movements (e.g., (32)) can be measured during real-world driving. It remains to be seen whether these technologies can provide reliable data while driving a racecar.

I suggest six (out of possibly many more) directions for future research relating to an embodied and an ecological approach to racecar driving:

## 5.1 Differences between experts and novices in perceiving overtake-ability (and acting upon it)

The ability to perceive overtake-ability on track is a necessity for racecar driving. One question is whether experts perceive overtake-ability when there is a gap not much bigger than the width of a racecar, compared with novices who may perceive overtake-ability only when the gap is larger than the width of a racecar. If so, are experts also able to act upon those perceived affordances successfully?

## 5.2 Underlying mechanism of improved perception of affordances in experts

If experts perceive relevant affordances better than novices, how do they accomplish that? One line of inquiry can include the gaze behavior of drivers. In a review of gaze behavior and expert performance, Brams et al. (33) showed that in sports, compared to novices, experts make more fixations of longer durations to areas of interest in the visual field. In this context, expert racecar drivers possibly make more fixations of longer durations to a possible gap. In contrast, novices may spend less time gazing at the gap, and thus detect less visual information relating to overtake-ability. Similarly, when approaching a turn, do experts spend more time gazing at the apex, and then as they reach the apex, direct their gaze towards the straight that follows the turn? Unfortunately, gaze behavior of racecar drivers or differences in gaze behavior between racing drivers and non-racing drivers can be found in only a handful of studies (e.g., (34, 35)) and to the best of my knowledge, those studies did not study gaze from an ecological perspective.

## 5.3 Can we teach novice drivers to improve their perception of affordances?

Training drivers in visual scanning of a racetrack is one direction for research. But there are other behaviors that can lead to improved performance. For example, the way drivers position their car on the track affects their field of view and their ability to detect actionable information. As Gibson (3) suggested "we must perceive in order to move, but we must also move in order to perceive." (*p*. 213). Racecar drivers can position their cars on track in a way that increases their chances of visually perceiving relevant affordances. Training studies can be conducted in which novice drivers face various racing and overtaking conditions. In such studies, car position and gaze behavior can be easily recorded.

### 5.4 What is embodied in race car driving?

It remains to be seen what constitutes the embodied cognitive system of the driver. Does the cognitive system only include the mind, the physical body, and the car? Does it go beyond the car? Is there a relationship between such embodiment and perception of turn-ability or overtake-ability? Answering such questions can lead to insights on expert race driving performance.

### 5.5 Do electronic sports (esports) drivers have different perception of embodiment and affordances?

Esports racecar driving competitions are of interest and some online e-races are streamed live. Pedraza-Ramirez et al. (36) suggested that esports psychological research is timely. From an embodied cognition approach, we can ask whether the sense of embodiment of esports race drivers differs from that of drivers on a real racetrack (e.g., does the cognitive system includes the virtual car?). Esports drivers can use a variety of set-ups that range from high-fidelity simulators to relatively basic seat-wheel-pedals systems. Add to the mix the use of VR and you will get a rich environment to examine what constitutes the cognitive system of the driver. From an ecological perspective, it is interesting to examine whether the perception of affordances differ when one does not sit in the actual racecar. Studies on these topics can help improve esports driving performance, but also provide insights into embodied cognition and perception-action coupling in general.

### 5.6 Perceptual attunement and (re) calibration

Perceptual attunement refers to the difference between expert and novices in the information they rely on to perform a task and to the ability to rely on more relevant information (27, 37). Expert racecar drivers rely on visual information (e.g., the apex of the turn), auditory information (e.g., engine sound in different gears), and haptic information (e.g., feedback from steering wheel, bodily sensation caused by g forces, sensations of the car losing grip). Research should examine to which of those (or other) variables experts attune to. Attunement to visual information can be examined with the use of eye trackers, but attunement to haptic information may require qualitative methodologies and "think aloud" protocols. Extending perceptual attunement to action, a process of calibration – scaling action to information (38) – is required. Moreover, in the ever-changing conditions of the car (e.g., tire degradation) and the driver (e.g., cognitive and physical fatigue), recalibration of actions is continuously required. Examining how race drivers are able to constantly rescale their actions to the changing information and still operate their racecar on the edge of its grip to maintain the highest average speed possible will be invaluable to the understanding of their perceptual-cognitive-motor abilities.

## 6 Conclusion

The purpose of this perspective paper was to show how an embodied and an ecological approach can be valuable in racecar driving research. Identifying what exactly is embodied and how racecar drivers identify and act upon affordances on the racetrack can improve our understanding of this fast-paced sport and allow us to provide better training for novice drivers. Moreover, such research could potentially improve drivers' safety as improving perception of affordances can reduce decision-making errors. It is also plausible that such studies can provide valuable information regarding other fast-paced sports as well. Hopefully, this paper will encourage researchers to conduct studies on this topic.

## 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.

## Author contributions

Author GZ conceptualized, wrote, and edited this manuscript. All authors contributed to the article and approved the submitted version.

## 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.

## Publisher's note

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# Blank canvas or under construction? Examining the pre-academy experiences of young developing professional team sports athletes

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**Introduction:** Extensive research has been carried out on Talent Development (TD) environments and an increasing amount of work shows the development of psychological characteristics as an important formal part of the academy experience. Importantly, however, very little attention has been paid to what types of skills, if any, young players arrive with. In other words, there seems to be an assumption that young athletes arrive at the academy as a blank canvas.
**Methods:** As such, to investigate whether players' arrive with these psychological characteristics, we looked across a sample of young footballers' and rugby players' personal experiences (such as, family input, sporting background or personal challenges) prior joining the academy. Individual semi-structured interviews were conducted, and data were analysed via thematic analysis.
**Results:** Our findings suggested that young athletes acquired an aptitude from general experiences, whereby they had already started to develop and deploy specific skills (such as, reflective practice, mental skills or seeking social support) to navigate particular challenges, prior to arriving at the academy.
**Conclusion:** Implications include the need for coaches and psychologists to assess young athletes' skillsets and pre-academy experiences upon arrival and use this as a starting point for developing tailored and individualised pathways that would enable them maximise their potential.

KEYWORDS

lose talent development, coping skills, challenge, post-traumatic growth, talent pathway, social support

## Introduction

A wealth of recent findings has suggested that young athletes follow an individualised, complex and, ultimately, non-linear trajectory to the top (1, 1–4). Given that a talented individual can be viewed as someone who possesses the potential to perform at a high level, research has focused on the skills required to negotiate the challenging pathway and realise this potential (5). Notably, a growing body of research has alluded to the central role of psychological characteristics in facilitating the development of talent (7, 6–9). Resultantly, current applied literature has focused on providing clear guidelines through which to ensure young athletes develop, deploy, and refine a toolbox of psychological skills along the TD pathway [e.g., (10–12)]. However, the extent to which young athletes already have (albeit early versions of) psychological skills when entering the academy

system remains largely undiscovered. This knowledge gap should be of particular interest given the important role better refined coping skills through the pathway can play in an athletes' ability to be successful (13).

Whilst most of the research solely focuses on the full TD pathway [e.g., (4)], Williams and MacNamara (14) recently attempted to bridge some of the existing gaps in literature by examining the experiences of young athletes in the early years of the pathway. Supporting previous findings in the area (4, 15–17), results indicated that young athletes utilised a range of psychological skills (e.g., commitment, goal-setting and performance evaluations, self-belief) and diverse social support to deal with developmental challenges.

Although some key assumptions could be made regarding the *types* of skills that young athletes utilise in the early years of the pathway, it is still unclear whether these skills were developed from these early academy experiences, or pre-academy entry. Therefore, another important point of exploration concerns the precise nature of *how* these characteristics are acquired. For example, there is increasing agreement that challenge plays a big role in developing these aforementioned skills [e.g., adversity related growth, (3, 18)]. Simply put, research suggests that adversity-related experiences are integral to testing and refining skills, as well as developing attitudes that performers already possess (4, 19). Notably, however, research has solely focused on the experiences of young athletes on the TD pathway (4, 20). Given the much less structured pre-academy pathways, it seems unlikely that young athletes acquire these important skills in such a formal manner through that period, indicating that similar development may also occur in unstructured ways [cf. comparisons between formal and unstructured development of musicians – (21)]. In short, development may be facilitated prior to joining the more formal academy systems but exactly how is unknown.

Moreover, the selection of young performers into highly structured TD pathways now occurs at an increasingly younger age (22). In an effort to identify and recruit the most talented young players, many football academies in the UK require players as young as six to attend several weekly training sessions, before their formal registration begins at 8 years of age (23, 24). As such, it could be argued that the exposure to a range of challenges prior to formal entry seems to be inevitable. Therefore, the early experiences of young athletes at a pre-academy level in preparation for the challenging and, often, unpredictable academy pathway should now become an area of great interest.

Reflecting the above, another important question extending beyond the timing of this development, concerns the mechanisms that underpin growth before entry. Namely, to clarify whether psychological skills are present before the occurrence of challenge (as experienced within the academy pathway) or if challenges themselves provide a platform for these skills to be developed. Against this distinction, previous research has suggested that the experience of negotiating challenges can generate growth through the process of deploying existing psychological skills (14, 20, 25, 26). Whilst the nature and incidence of learning-specific and general challenge before entry remains largely undiscovered, this debate is of even greater importance.

To summarise, several TD studies in sport have indicated that more successful athletes made use of better refined coping skills through the pathway [e.g., (13, 27, 28)], but when and how they learned these skills remains unclear, prior to their exposure to the formal tuition and testing regimes which characterise effective academies. Therefore, the aim of the present study was to examine the extent to which these young players arrived with skills or as a blank canvas when entering an academy. Specifically, first of all, we explored the types and origins of coping skills these young players already had developed prior to entry, and secondly, the *role* of challenge in the learning and development of these skills. Indeed, if challenge played a role, then we looked to explore the perceived nature and timing of these challenges for the young football and rugby players who had just entered the academy system.

# Methods

## Research philosophy and design

Aiming to find solutions to real world problems through the initiation of practical knowledge, a pragmatic research philosophy (29) was deemed most appropriate in this study. Unlike other paradigms whose processes are largely driven by matters of ontology and epistemology, pragmatic research is primarily interested in answering questions that are important for those in applied settings (30). Nevertheless, it is important to highlight that pragmatic enquiry is undertaken from a clear philosophical base (31) which guides all stages of the research process. Thus, instead of focusing on the elicitation of generalised realities or subjective constructions, our efforts were channelled into the identification of applied artifacts that would deliver applied impact for coaches, practitioners and key stakeholders (29) in the context of TD in sport. To explore the skills, experiences and reflections of young athletes who have recently arrived at formalised TD pathways in sport, a qualitative methodology was adopted (32). Importantly, we also considered ourselves, the researchers, as co-constructors of knowledge (33). Therefore, in accordance with the basic tenets of pragmatic philosophy, this study was facilitated by our applied knowledge, skills, and experiences of working and performing in elite sport talent pathways (29). In this regard, Bryant (34) posited that, practical knowledge and personal biases can offer an innovative insight. In essence, research-derived knowledge and experience-derived knowledge (34) both feed into each other as applied settings evolve (35).

## Participants

Given the stated aims of this study, we set out to recruit young performers from four elite academies in two professional team sports. Specifically, 14 young male performers (seven football players and seven rugby players) aged between 10 and 14 years were purposively recruited. We requested clubs to nominate players they identified as having the most potential to achieve at the highest level. Their recent arrival at academy systems was

intended to support accurate recall of events experienced prior to entering an academy system and address issues that might have arisen in retrospective interviews with older performers. More specifically, varying participant ages occurred due to sport specific differences, whereby football players can enter the academy system at the age of 8 while rugby players do so at the age of 13. In short, all were within two seasons of academy entry.

## Procedure

Once ethical approval was obtained from the authors' institutional ethics committee, professional sport academies were initially approached and provided with a written proposal about the purpose, the procedures, the timescale (and input required from participants), and planned outcomes of the study. Participants meeting the criteria were invited to participate through personal contact, *via* a gatekeeper (for example, the age-group coaches), then informed consent was gained from each participant prior to their interview with confidentiality assured. As players were all under the age of 18, parental consent, along with participant assent, was also secured.

To facilitate the ease of discussion and ensure consistency throughout the interviews, a semi-structured interview guide was developed (see **Table 1**). The guide consisted of open-ended questions and relevant follow-up prompts and probes adjusted to suit the background of participants (e.g., age, stage of development) with the aim of gleaning as much pertinent information as possible. Specific probes and prompts were also used for clarification and elaboration of key points and to obtain consistency in the depth of responses (36). This guide was informed by relevant TD literature and conducted on the base of a retrospective-tracking protocol that has been previously employed to draw out specific details on personal experience (37, 38).

Data collection was arranged in two parts. In an effort to ensure accuracy and validity of recall, participants were given the opportunity to anchor their recall of incidents to particular times and events. According to Drasch and Matthes (39), this approach can address some of the limitations of retrospective recall inherent in this method of data collection by ensuring participants related their experiences to the key stages that applied to their own pathway. Therefore, in the first stage, participants in collaboration with the interviewer developed a trajectory chart of their career on a standardised grid. Following this, guided questioning was implemented utilising the standardised interview guide. This allowed for an in-depth examination of the different experiences encountered along the TD pathway encompassing both sport and non-sport related events. Building on this stage of questioning, the second part addressed a retrospective reflection on "traumatic" or impactful events including psychological challenges experienced, methods employed, significant other/coach inputs and lessons learnt.

## Data analysis

All interviews were transcribed verbatim with each interview lasting approximately 30 min (20–40 min). Following this, and using the self-drawn trajectory charts, participants' experiences were tracked across the pathway process. Drawing on these retrospective accounts, alongside players' subsequent viewpoints, inductive content analyses were conducted (40). This encompassed reading and re-reading the transcriptions followed by employment of qualitative analysis software (QSR NVIVO 9) to transform raw data units into thematic hierarchies by engaging in tag creation, category creation, and category organisation (41).

## Trustworthiness

All interviews were conducted by the first author who developed trust with the participants, achieved by demonstrating a genuine appreciation of their history and current situation, as well as the demands of their development and performance experiences. Essentially, this process was further facilitated by the authors' roles in TD pathways and as such, knowledge of the themes being discussed.

TABLE 1 Interview guide.

| Purpose | Question | Prompt | Analysis |
|---|---|---|---|
| Examination of Pathway prior to joining the academy; key incidents, identified critical incidents. | Using a timeline, can you draw me your pathway up to joining the academy? | When did you start and how? What sports did you take up? What did your early experiences look like? What did they mean to you? What were the biggest ups and downs (i.e. sport and/or life challenges)? What were the biggest learning experiences? What did you learn that was subsequently useful? For example, specific skills?? *Using the timeline drawn by participant:* What helped you the most here? *(Pointing to challenging occasions)* Who helped you the most here? *(Pointing to challenging occasions)* | Nature of Involvement Measure and description of early experiences Measure and description of past critical incidents Major critical incidents – stand out as being significant incidents Positive and negative developmental impact of challenges Psychological characteristics possessed, developed, deployed What skills did they have? Skills developed through challenges. Social Support |
| Retrospective examination of specific critical incidences | What were the most difficult experiences or events (if any) you had prior to coming into the academy? | Why was it challenging? Were you prepared for it? What helped you the most? How? Who helped you? How? What do you think you learned from it? Can you give me examples? What would you have done differently? | Major critical incidents Positive and negative developmental impact of challenges Did they possess the skills to make the most of the opportunities available? Skills developed through challenges. Social Support |

Trustworthiness of the data analysis process was also facilitated by QSR NVIVO's optimisation of transparency [cf. (42)]. A reflective journal was maintained by the lead researcher to reduce the likelihood that interpretative bias affected the data analysis (36). The use of constant comparison method provided the platform for challenging first author's data interpretations (35). Specifically, the second author read the full transcripts of all 14 interviews and reviewed the labels/codes created by the first author. When discrepancies in interpretations were found and/or concerns about potential interpretative bias arose, reflective discussions took place until a mutual consensus between authors was reached (43). To further ensure that the first and second authors remained mindful of their assumptions and presumptions, the third author acted as a "critical friend" throughout by generating rigorous scrutiny and in-depth exploration of the interpretations, explanations and meanings emerged from the data analysis process (44).

Additionally, analysed interview transcripts were returned to each participant *via* email to allow subsequent member reflections (45). This process involved a 10–20-min face-to-face conversation to discuss the emerging results, specifically the accuracy and validity of quotes considered for inclusion in the paper from that individual together with any additional reflections which occurred to them. Indeed, eight participants provided additional details regarding their experiences and skills developed pre-entry, further enhancing the robustness and richness of our findings. Pertinent information was reintegrated into the process of data analysis. Finally, feedback was sought on the researcher's interpretation of these quotes and the context of the results subsection in which they would appear.

# Results

The aims of this investigation were to explore (1) the types/sources of coping skills these young players already had or have developed to deal with early challenges and how these evolved, and (2) the nature and timing of challenges perceived to have helped young football and rugby players who had just entered the academy system to learn and develop their coping skills *before entry*. The results begin with an overview of the participants' self-reported coping skills, as displayed in **Table 2**. For clarity, these results were developed from the process of reflecting on their pre-academy experiences, including the process of navigating and negotiating challenges. Secondly, we then consider participants' experiences through which these coping skills were acquired. These themes are displayed in **Tables 3**, **4** in a chronological order. All these themes are presented in the results section with exemplar quotations to illustrate the analysis and the percentages of participant reporting each theme. These percentages are displayed to demonstrate the frequency with which participants offered certain responses, they are not intended to display any differing importance or value of the findings.

## Coping skills

When exploring the skills developed and applied pre- academy, all participants were able to note a number of coping mechanisms. Specifically, these mechanisms were conceptualised as mental skills, soliciting and using social support, and learning skills (see **Table 2**).

### Mental skills

Support for the development and application of mental skills before entry was pervasive throughout the data. As shown in the **Table 2**, participants commonly referred to motivation as an important mechanism for coping with early memorable challenges. Among others, they reported utilising motivation to handle different challenges including the stressful period of academy trials, criticism from others and non-sporting incidents such as loss of a family member. Essentially, motivation was described as being demonstrated in a variety of ways, including genuine love for the sport, desire to develop and succeed, willingness to put in hard work, motivation to prove others wrong and making people proud. It was also recognised more generally in terms of overall motivation. For example, R5 described, "motivation is a key factor determining your success in whatever you do, whatever you're going through… No matter how difficult a challenge can be, it's my motivation that drives me."

In addition, self-efficacy was also consistently identified as another key mechanism in facilitating the participants' endeavours in the early years. Once again, the way self-efficacy manifested varied among participants, with analysis revealing several sub-themes such as belief to excel despite challenges, confidence to engage with challenges, setting high personal standards and unshakable belief despite others' doubts. Importantly, both the motivation and self-efficacy that propelled the participants' efforts in handling these situations seemed to be present *before* the occurrence of recalled incidents.

Moreover, in their accounts of events the participants highlighted focus as a key mental skill for effectively negotiating early challenges. This focus was predominantly directed to specific goals that took either the form of process targets that were within the participant's control (e.g., making the right decisions) or outcome targets (e.g., be successful on trials). The importance of distraction control was also discussed by participants. Specifically, they referred to an ability to *block out* distractions and direct attention to the most important aspects of development and/or performance. Interestingly, however, some reported *using* distractions as a means of dealing with difficult challenges (e.g., long-term injury).

As another key mental skill, participants noted how *self-awareness* of their strengths and weaknesses helped them to handle early challenges. Importantly, this heightened awareness and, more generally, the process of skill-refinement was often facilitated by social support factors and underpinned by an ability to reflect on personal experiences (i.e., learning factors), both of which mechanisms are discussed next.

TABLE 2 Self-reported coping skills .

| Umbrella Theme | Higher Order Theme | Lower Order Theme | Exemplar Quotes |
|---|---|---|---|
| Mental skills 100% | Motivation 100% | Genuine love for the sport 86% | "I used to see it as a challenge. But I was not really worried about it. It's more about playing and enjoying the game. When you're younger, all you want is to have fun, so I let myself enjoy it" (F2) |
| | | Desire to develop and succeed 86% | "I was a lot more determined than other players. You know… a personal drive… I did a lot more extra training than the other players. I wanted to improve, I wanted to learn the game and get to their level" (R4) |
| | | Willingness to put in hard work 93% | "It was a rocky start, a bad couple of sessions I remember. But that motivated me to work harder in and out of training" (F6) |
| | | Motivation to prove others wrong 21% | "I wanted to prove them wrong, that they made the wrong decision. I wanted to show them what I was capable of. If you are being passionate about something, you will achieve it." (R6) |
| | | Motivation to make people proud 50% | "Because my Granddad always wanted to come and watch but couldn't. So, when he died, it motivated me more to try harder and get to the top." (F5) |
| | Self-efficacy 100% | Belief could excel despite challenges 86% | "Well, I was playing against some of the best players in the area. I used not to think about it when on the pitch… I was confident in myself; I knew I could deal with it." (F1) |
| | | Confidence to engage with challenges 86% | "I loved the idea of playing against the best and being watched by the best coaches in the area. I mean, it makes it more exciting" (R2) |
| | | Setting high personal standards 67% | "I discussed this with my dad. We decided that signing for Academy B would make me a better player, it was more challenging. You need to be confident to push yourself out of you comfort zone" (F5) |
| | | Unshakable self-belief despite other's doubts 21% | "Even though most of my friends were doubting my skills, I knew I had it… I believed in myself, I believed that I could become the best." (R4) |
| | Focus and distraction control 71% | Ability to focus on the task at hand 50% | "I did not want to let my emotions get the better of me, I focused on what I was about to do and dealt with mistakes after" (F3) |
| | | Focusing on own goals 50% | "My goal was to progress and be the best I could be. It was hard leaving friends behind but had to think long term" (F5) |
| | | Ability to block out distractions 43% | "I did not want to let their opinion distract me so I just tried not to listen to it. I focused on the feedback from my coaches and worked hard on it." (R4) |
| | | Using distractions as a coping mechanism 21% | "So, I tried to have fun, like playing XBOX instead of focusing on my injury all the time. Doing stuff that you can without putting stress in your engine." (R2) |
| | Self-awareness 64% | Awareness of strengths and weaknesses 64% | "You must work at it all the time. You have to focus on the professionalism. Most of my friends were talented and I wasn't talented at all, but I was passionate. My attitude was my biggest strength." (R4) |
| Soliciting and using social support 100% | Identifying available social support 100% | Recognising the value of social support 100% | "It was hard (i.e., injury) and my parents were always there for me, whatever I needed. They were saying positive things like 'it is going to be fine' and we would do things that would make me feel better" (R2) |
| | | Distinguishing between positive and negative social support 50% | "Unlike my teammates, my coach was very supportive. I was disappointed, but he showed confidence in me. He said, 'if you take my feedback on board and work hard, you will be in the first team squad soon" (R4) |
| | Mobilising social support resources 100% | Soliciting and using social support when needed 100% | "I was friends with N and E from grassroots, so they helped me a lot. They would speak to me in the dressing room and introduce me to the others. They made me feel comfortable." (F2) |
| | | Managing the impact of social support 50% | "There was a lot of pressure, they believed in me. But, telling me 'You have the attributes, you need to be the best etc' didn't work for me. So, I decided to talk to them and explain how I felt." (R3) |
| Learning skills 100% | Reflective practice 100% | Ability to reflect and make sense of own experience 86% | "I tried to dribble past them but failed. They were older, stronger, and taller than me. I wouldn't be able to match them physically. I realised that I needed to change my game, move the ball quicker" (F4) |
| | | Identifying areas for improvement 64% | "I discussed this with my dad and decided that I needed to improve my physicality, to become faster and stronger" (F6) |
| | Identifying and using learning from previous experience 100% | Perceiving challenges as growth opportunities 86% | My coach was saying 'you either win or learn'. Nobody wants to struggle with things, neither do I. But those struggles are opportunities to learn." (R7) |
| | | Identifying and applying lessons learnt 71% | "I learnt how to focus on getting the next thing right and not thinking about a previous mistake as this would make me angry" (F7) |
| | | Draw confidence from prior experience 86% | "During trials I had to play against older players but didn't affect me. In grassroots, I had played against older boys a couple of times, so I had the confidence to do it again." (F2) |
| | Identifying and using learning from others' experiences 86% | Ability to learn from others' experience 71% | "The way my dad handled it taught me how to stay strong and positive whatever the situation is. He was there for my mum who was having chemotherapy, he supported me and my brother, always being positive and optimistic. There was not a moment making us feel something would go wrong." (R1) |
| | | Applying learning from vicarious experience 64% | "My brother was playing for the older group and obviously prepared me a lot. I used to watch him training so I knew what to expect and what I needed to do" (R2) |

TABLE 3 Nature of general experiences as part of early involvement with sports.

| Umbrella Theme | Higher Order Theme | Lower Order Theme | Exemplar Quotes |
|---|---|---|---|
| Initiation to sports 100% | General Experiences 100% | Early exposure 100% | "I started playing rugby when I was 3. I was quite young really" (R1) |
| | | Fun and challenging activities 100% | "When he used to come around, he'd bring a football and some cones, and he'd teach me how to dribble in and out of the cones." (F3) |
| | | Multi-sport experience 100% | "I have done loads of different sports in my life. For example, I used to play football. I have also played some basketball which I really enjoyed as part of PE at school." (R6) |
| | | Early success 86% | "I was playing for a local football club and after a few months, the coach told my dad I was getting on really well and maybe they should take me to a Sunday League Club. I was so happy" (F6) |
| | | Playing for a team 100% | "I started playing football when I was about four. I was young, playing for a local team." (F2) |
| | | Watching sporting events 100% | "I was watching sports since I was like 3 or 4. It is part of the family, we were going to the matches and supporting the local club." (R7) |
| | | Observing family members 64% | "My dad was coaching a rugby team at the time and would get me along to watch his training sessions. It was part of the family culture and quickly passed on to me" (R2) |

TABLE 4 Nature of reported challenges Pre-entry.

| Umbrella Theme | Higher Order Theme | Lower Order Theme | Exemplar Quotes |
|---|---|---|---|
| Challenges 100% | Sport 100% | Academy trials 64% | "My first training session on trial was tough, much harder than the Sunday League. I didn't think it was going to be that hard. It took me some time to settle. It was very competitive; everyone's eyes are on you" (F6) |
| | | Playing up 50% | "I remember when I was at the Development Centre, they got us to train with the U9s a couple of times. It was a very hard challenge" (F7) |
| | | Underperformance 43% | "I would fume inside; I couldn't afford making mistakes. I needed some time to get my head back up after poor mistakes. At the time, I thought of a bad performance as a step back. It could make me sad" (F3) |
| | | Physical 36% | "I think I could keep up with the technical side, it was mainly the physical side. Whenever you tried to get on the ball, they would do it faster than you. They were stronger and better in reading the game." (F5) |
| | | Game changes 36% | "Obviously being used to tag rugby moving on to touch rugby was a bit of challenge. I needed some time to fully understand the game and tactics. It requires different mentality and approach" (R6) |
| | | Rejection 21% | "I was in the third team and I was quite upset by that because I could see the other players in the first team, they were starting for the first team all the time and I was a bit jealous" (R4) |
| | | Late start 21% | "It was the lack of experience, I struggled to understand the game, where to go, how to move. I was really enjoying the game but could not follow the pace. There's much to learn while others had already progressed" (R3) |
| | | Injury 14% | "It was big to hear that I would be out of sports for the whole summer… Yeah that was hard because when you are young all you want is you know… running and playing around and that is it" (R1) |
| | | Choosing between academies 14% | "When I got 8, I had to sign. I was at Academy A and Academy B at the same time, but I had to decide. It was very difficult because they're completely different teams. I also had very good friends" (F5) |
| | Environmental/ Social 64% | Adapting to new environments 43% | "When I was young, going into the dressing room at seven, I cried. It was scary. Because I was so young, I didn't know many people here, so it was all different people, it was nerve racking coming in." (F2) |
| | | Criticism from significant others 43% | "During trials, my friends were in the first team and I was in the second. They were like 'how come you're doing this, you shouldn't be going to do it'. That was initially dragging me down a lot." (R4) |
| | | Leaving family/ friends behind 36% | "One of the downs was probably picking a team, between Club A and Club B because it was leaving people behind. But also, I knew either of the decisions were good. Leaving my friends behind was tough though." (F5) |
| | | Pressure from significant others 21% | "When I started playing rugby, there's a lot of pressure on me. Because of my size, people expected me to be dominating the game. Well now I am that player… but back then I was not aware of the rules, I did not know the game… I was lost." (R3) |
| | Family 29% | Bereavement 21% | "I lost some family members and that was traumatic really. It's always a shock… I was shocked. I had to deal with the idea of them not being around anymore" (F4) |
| | | Illness 7% | "My mum was diagnosed with cancer in 2013. That was probably the most difficult challenge I have ever been through. A huge down… I could not focus on my rugby and school. But, how could you really?" (R2) |
| | Logistical 29% | Balancing commitments 29% | "At the time, I found it difficult to balance commitments. I was playing school rugby with the 11s and 12s, traying with a club once a week plus some swimming. It was tiring really" (R5) |
| | | Travel commitments 7% | "Before I started playing rugby, I wanted to join a football club. But my mum couldn't support me as we lived far away from the training centre. That was a big down as I had many friends playing for that team" (R3) |
| | Educational 7% | Drops in school performance 7% | "Then in year eight, I started getting distracted from school because I was so worried about my rugby. I realised that I was not getting on well and I had to balance it" (R4) |

### Soliciting and using social support

All participants discussed the value of identifying and mobilising social support in navigating their way through the developmental "ups and downs". In this context, family support played a key role. Among others, this involved parents providing emotional support after setbacks, offering feedback, sacrificing resources to offer extra training and older siblings encouraging the participant prior to and during the intense period of academy trials. Albeit less discussed within the interviews, coaches and friends seemed to also form another part of the participants' support network. Notably, coaches often acted as a source of self-efficacy by displaying genuine appreciation of the participant's circumstances whilst providing specific feedback tailored to support their needs. Interestingly, participants indicated that social support was not merely utilised in a reactive manner to negotiate challenges but also proactively in preparation for future challenges.

Although the participants often indicated a preference for utilising one support resource over another, the strength of coherence among one's support networks was also outlined. The following excerpt of a rugby participant whose mother was diagnosed with cancer epitomises how a coherent support network can be key to effectively navigating a memorable life challenge:

> It was a big trauma. My dad and my older brother were both really supportive. I think these moments bring families closer. My dad would give us courage… He said positive things like 'Everything is gonna be fine, we need to be patient'. My older brother provided emotional support, he listened to me. My friends and teachers at school also offered to help. My friends know me … I am a bit close as a person but being there for me was reassuring. Eventually, I used their support, and this was a bit of a relief (R1).

Despite the apparent advantages of such coherent networks, this was not always viable as not all support environments were identified to be positive by the participants (e.g., friends being a negative influence). Thus, employment was underpinned by an ability to distinguish between positive and negative support environments. In this regard, participants commonly stressed the need for careful and effective *management* of social support resources available. Essentially, the participants asserted that social support should be tailored and deployed in an appropriate way.

### Learning skills

Another crucial attribute consistently reported by all participants was learning skills. The ability to make sense of experiences and outline areas for improvement through the use of reflective practice was reported by all participants. Interestingly, participants commonly alluded to the value of reflective practice both from micro-level and macro-level perspectives. This process was portrayed as an in-depth evaluation of an experience that enables the discovery of underlying reasons of a challenge. This is best illustrated by the quote below:

> "It was very different from Sunday League. I had to catch up. They were physically better, they also made quicker decisions. Me and my dad sat down and discussed what and how to improve. We thought I needed to work around my fitness, trying to get stronger and faster. This was something that would make me a better player" (F6)

Of course, as implied here, there appears to be clear aspects of learning resulted from this reactive process. Such learning was reportedly implemented by athletes in a proactive manner to reduce the likelihood of similar challenge occurring in the future. This signified an ability to identify and apply learning from previous experiences of handling developmental challenges.

Interestingly, vicarious experience was identified as another source of learning experience that helped performers cope with memorable challenges. To clarify, participants reported drawing knowledge, experience and, ultimately, confidence in an ability to cope with challenges from observing and reflecting on significant others' experience.

## Nature of experiences

Tables 3, 4 depict the nature of the experiences before entry, and the frequency with which they were reported. Experiences are presented in chronological order to provide an insight into the process that facilitated the genesis and subsequent development of coping mechanisms shown in Table 2. Data indicate that, as a result of their general experiences participants acquired a tendency or aptitude which then became synthesised into a more focused skill as a result of a challenge. Indeed, all general experiences reported occurred between the age of 2–7 with first memorable challenges reported no earlier than the age of 6 ($M = 7.8_{\text{years}}$, SD = 1.2). Importantly, further evidence of the genesis of these skills was shown in Table 2. Social support and learning factors formed part of the broader upbringing along with the general experiences reported to have played an important role in the early development of this identified aptitude.

### General experiences

Participants were asked to reflect on their initiation and start in sport. All participants reported an early exposure in sports between 2 years old and 7 years old ($M = 3.8_{\text{years}}$, SD = 1.1). The family influence was referenced by many as an inspiration to take up sports. Indeed, participants reported that sport was an integral part of their family culture. This involved other family members being former professional athletes and/or older siblings actively taking part in sports.

Early years experiences typically involved regularly taking part in a range of fun and challenging activities and attending/watching sporting events. Participants also reported playing sporting activities in the back garden or the local park. These activities were largely organised and supported by the parents. All

participants believed that these family activities had positively facilitated their motor skill development as well as contributed to their motivation and positive attitude. In addition, participants suggested that the challenging and competitive activities had contributed to the early development of their aptitude. Importantly, playing for a team from an early age was reported as having an important impact on their development. All reported participating in a range of activities from an early age and this multisport experience was also perceived to have contributed to their successful development within their main sport.

All but three participants reported experiencing early success which was perceived to have contributed to their confidence levels. Notably, this early success was influenced by positive feedback provided by parents or being identified as a talent from an early age.

## Challenges

Early challenges appeared to be highly idiosyncratic, with young performers' interpretations on what constitute a challenge varying greatly. Sport challenges constituted the largest proportion of the experiences reported as having an important impact on their development. As per **Table 4**, an early memorable challenge consistent amongst players in both sports was the intense period of academy trials. Being selected to play for an older age group, was another early sport challenge that the participants commonly referred to within their interviews followed by underperformance. In essence, participants described the difficulties experienced when they had to compete against older players and the emotional upheavals resulting from poor performances. Importantly, playing a year up reportedly carried secondary challenges, such as those of physical nature. Besides this, however, the occurrence of *physical* challenge was also described as being determined by other factors, including sport-specific demands and individual differences. Indeed, some participants encountered physical challenges due to them being less physically developed than their counterparts. This was particularly challenging for rugby participants where the nature of the sport, which requires high levels of strength and physicality, can add-up to a potential existing handicap resulting from a less developed physical outlook "You know I was small and, obviously, other players would outplay me in most game scenarios. Rugby requires physicality. I mean it is a full-contact sport." (R1)

Within sport challenges, having to adapt to games changes was particularly challenging for some participants whilst rejection was also identified as an early hurdle. Whilst injuries can be an inherent part of sports participation, players indicated that being forced to stay out of sports due to an *injury* could be immensely challenging, especially at an early age. Finally, less frequent among challenges of a sporting nature, and perhaps indicative of the highly idiosyncratic incidence of early experience, were challenges concerning a late start in their main sport and decisions about choosing between academies.

In addition to the sport related challenges described above, a large proportion of participants indicated some social/environmental challenges that seemed to have had an impact on their development. Interestingly, however, all those challenges appeared to be closely linked to and/or a result of sport involvement. For example, settling into a new team at an early age seemed to be a stressful experience for many participants. In addition, even though siblings and friends can act as a strong support network for young developing athletes, they may also be a significant source of stress. This was discussed by participants who identified perceived criticism from significant others as a profoundly difficult experience that could initially affect their emotional states. Along the same lines, some participants described the levels of *pressure* experienced when significant others verbalised their unrealistic expectations of them. Finally, the challenge of having to leave friends behind was preceded by a decision to choose between academies and/or change a sporting environment.

Whilst less pervasive throughout the data, perhaps due to the unforeseen and serendipitous nature of them, some participants referred to family challenges as having an impact on their development. This predominantly involved incidents of bereavement with unpredictable *illness* far less common. Even though reported, however, the rate of incidence was far less than suggested by some literature [e.g., (46)] and more in keeping with other concurrent work [e.g., (10)].

Devoting time to sports can often bring some additional challenges for the young performers. For instance, the challenge of *balancing commitments* was recognised by four participants. Less evident throughout the data were logistical issues concerning *travel commitments.* Finally, another challenge that emerged as a result of sport involvement was *drops in school performance,* although this was only reported by one participant.

# Discussion

Coping skills have been shown to play an influential role in helping young individuals to realise potential in various performance domains such as sport, business and dance (47–49). The purpose of this study was to deepen understanding about the extent to which young players arrive with skills or as a blank canvas when entering an academy. The design of this study allowed participants to explore their reflections of their experiences and skills developed and utilised before entry.

Notably, the findings of this study contribute to a deeper understanding of the growing area of TD research (4, 14, 16, 17) by showing that young performers arrive at the academy pathway with a fledging set of coping skills. Interestingly, there appears to be a stark similarity between the nature of coping skills reported in the present paper and those previously identified in the TD literature. More specifically, mental skills found in this study (e.g., motivation, self-efficacy, focus and distraction control) overlap with those reported in prior work (4, 7, 8, 14, 50, 51). Unsurprisingly, motivation and self-efficacy seemed to be particularly important in the early years, perhaps

due to them being key drivers of commitment and involvement. In addition, although the importance of diverse and coherent social support is well-established in TD literature [e.g., (15, 52)], our results indicated parents as the primary "providers" of this support in pre-academy years [cf. (53)]. Moreover, the key role of learning skills through the use of metacognitive strategies (e.g., reflection, evaluation) has been extensively discussed in prior work (7, 9, 54). Taken collectively, such findings further solidify previous suggestions about the importance of psychological skills, social support and learning skills in facilitating the development of talent. However, the level and confidence in ability to use the skills may not be necessarily identical to that of more experienced athletes reported in previous studies [e.g., (4, 14)].

Further, our findings provide a novel insight into the genesis and early development of these coping skills before entry, a matter, until now, which has remained largely unconsidered. More specifically, the results suggest that children, as a result of *general* experiences and upbringing, acquired an aptitude which then became synthesised into a more focused skill as a result of *specific* challenges. In terms of the nature of these general experiences, these findings support evidence found in the physical literacy literature. Indeed, the benefits of early motor skill development and physical competence have long been linked to heightened confidence (55) and increased motivation to maintain physical activity throughout life (56, 57). Moreover, early success has been associated with confidence and motivation in sport (58). Finally, the early experience of working in teams can have many benefits such as acquiring social skills (59), positive self-perceptions, enjoyment, and persistence (60).

Within the spectrum of general experience, parental involvement and associated behaviours seemed to play a key role in the development of this aptitude, supporting previous findings in the area. Beyond the influential role parents can play in socialising children into sport (61), they can also influence their child's psychological functioning and cognition in sport [e.g., (62–64)]. Recently, Teques et al. (65) found that parental support through the use of reinforcement, modelling and encouragement was associated with higher levels of self-efficacy, social efficacy, intrinsic motivation, and self-regulation among young performers in a range of team and individual sports. Indeed, parents are the main source of influence during this time (66), whilst young performers develop their perceptions of physical competence and self-confidence that can aid both their long-term development through sport and their chances of maximising their potential (67, 68). Ideas of strength-based parenting are also clear from our data [cf. (69)] whilst the lack of intrusion style also match earlier research [e.g., (10)].

Moreover, these findings support previous work in adversity-related growth literature [e.g., (4, 70)]. Unlike TD environments. Importantly, however, challenges experienced before entry appeared to offer an opportunity for young athletes to turn an aptitude acquired from early general experiences and upbringing into a more focused set of skills to solve particular issues. This could shed light on the ongoing debate over the mechanisms that underpin growth following adversity (e.g., 73). More specifically, our findings suggest that previous suggestions regarding the role of challenges should not be seen as opposing poles of the same stick but rather as complementary views that address the same matter. As mentioned, some mental skills and social support were present before the occurrence of challenge [cf. (25)]. Notably, when faced with a challenge, participants relied on previous personal and/or others' experiences to inform their response. Importantly, the process by which meaningful lessons were drawn through the use of reflective practice indicates that, while challenges can set the preconditions for subsequent learning and development to occur (70), it is also the learnt skills that young athletes deploy to deal with those challenges that seems crucial (10, 25).

Whilst there seemed to be key similarities in the types of early general experiences that enabled young athletes to develop an aptitude, the nature of challenge that underpinned the subsequent synthesis of more focused skills were highly idiosyncratic. In line with prior work that focused on the experience of athletes whilst on the TD pathway (4, 14, 70, 74), the nature of the challenges recalled in this study were complex, including both sporting and non- sporting issues.

Regarding the timing of the challenges, these findings extend current understanding of perceived trauma occurring at the early stages of sport participation which contrast previous assumptions reported by Savage et al. (4) positing that perceived traumas occur no earlier than 7 years after commencing a sport. To clarify, Savage et al. (4) contended that perceived and memorable traumas can be seen as those experienced in the initial phases of investment (75), perhaps because the impact of challenge may be greater at this stage due to the high levels of time and commitment invested by young athletes. However, our findings indicate that young athletes (at least these who were identified as of greater potential) not only face challenges in sampling years, but that those challenges seem to play a pivotal role in the subsequent development and refinement of their existing coping skills.

Reflecting this, there are several messages from the ways in which skills are acquired and implications for TD environments. The results from this study are in contrast to the sole and formal construct of post-traumatic growth or as suggested by Collins et al. (10) teach-test-tweak-repeat. Of course, that is not to say that this does not happen, nor that this is not a useful strategy for performers once in the academy. Instead, our findings posit that upbringing and appropriate general experiences have led to an aptitude or tendency (cf. Proactive coping – 76). That aptitude is then utilised to solve particular issues, such as different developmental challenges. The impact of early familial and general sport experiences is much more akin to physical literacy because the armoury of skills is, unsurprisingly, not taught in a formal sense.

As such, if children are arriving at academies with an established aptitude and an early version of skills, it is important that early on practitioners assess athletes' skill provision, or toolbox, and use this as a starting point for development. Additionally, information regarding the types of experiences and challenges young athletes face prior to embarking on the TD process could facilitate the deployment of appropriate

experiences. Indeed, akin to recent calls for strategies that would optimise TD structures (14), this information should provide the platform for TD stakeholders to individualise young athletes' pathway through preparation processes (assessing, teaching), reflection processes (tweaking) and, ultimately, periodisation of developmentally appropriate challenges in the early years of the talent pathway. Of course, it is important to note that there are more implications regarding parenting, early sporting development and pre-academy pathway structures, however this sits outside the scope of this paper and would warrant further investigation.

Supporting the call for longitudinal and prospective research in TD (73, 11), it would be beneficial to our understanding to follow up with these players to identify how they then continue to develop once they are in a much more structured and skills-focused level of the academy. Essentially, it may be important to closely investigate the evolving and dynamic nature of negotiating difficult challenges as young athletes' transition further on the talent pathway. Research on this topic could also compare the skills of talented athletes in different professional sport contexts. For example, players enter the academy system at a much later age in rugby, which may suggest that young rugby players arrive with more established set of skills at the academy as a result of broader experiences and challenges encountered.

Of course, this study was not without limitations. For example, due to the retrospective nature of data collection, there is a risk of recall accuracy (77, 2005). Although careful steps were taken to proactively address some of these limitations (e.g., recruiting participants who have recently arrived at the academy system), participants recalling events that occurred years or months ago can have resulted in lower accuracy of reports. Moreover, given the personal nature of reporting highly experiential accounts, there is a risk of impression management. That is, participants may have provided overly positive and growth-stimulating accounts of their pre-academy experiences, including challenges encountered and skills acquired/deployed, compared to their actual experiences. Furthermore, no steps were taken to triangulate the skills and experiences of the participants with questionnaires and/or with views from significant others such as parents and coaches. This would have potentially provided a richer picture into the skills that those young athletes arrived at the academy as well as the experiences through which those skills were acquired. Finally, it should be stressed that all participants were "highfliers" within the academy. It may be that, were we to have examined their less successful colleagues, a less positive picture would have emerged.

Notwithstanding the above shortcomings, as approaches to optimise trustworthiness (cf. Methodology section), methodological coherence was aided by framing our questions, purposeful selection of participants, methods, analyses, and interpretation in a pragmatic research philosophy (29). In accordance with our pragmatic philosophy (29), we believe the findings of this study provide contribution to practice-oriented theory and consultancy.

In conclusion, this study provided evidence that young athletes arrive at the academy with an early version of coping skills. Whilst the influential role of coping skills in facilitating learning and development is well-reported in prior TD work (1, 14, 16, 78), this study also investigated how young athletes learn, develop and deploy coping skills in much less structured environments such as the pre-academy life. Finally, talent pathway practitioners may significantly benefit from systematically assessing the young athletes' skills and pre-entry experiences upon arrival. This will enable these practitioners, supported by all stakeholders, to subsequently develop and deploy tailored programmes to support young athletes at the beginning of and along the pathway.

## 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 Oxford Brookes University Ethics Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## Author contributions

This article forms part of the PhD thesis of FP (currently undertaking at Oxford Brookes University) with title "Challenge and Trauma on the Talent Development Pathway". RC is the PhD supervisor of FP while DC acts as an external supervisor (specialist in the field). The authors indicated made substantial contributions to the following tasks of research: Initial conception and formulation of research goals and aims (FP), research design (FP, DC), provision of resources (FP, DC), data collection (FP) analysis and interpretation of data (FP, RC and DC acted as critical friends), writing and revision of paper (FP led write-up with RC and DC contributing to the revision of the paper). All authors contributed to the article and approved the submitted version.

## Conflict of interest

Authors RC and DC were employed by company Grey Matters Performance Ltd.

The remaining 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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# Advice from "pracademics" of how to apply ecological dynamics theory to practice design

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There has been an increase interest in knowing and enacting pedagogical approaches such as the Constraints-led Approach (CLA) and Nonlinear Pedagogy (NLP) which are underpinned by Ecological Dynamics in recent years among practitioners. While there seems to be a perceived uptake of such pedagogical approaches that encourages exploratory learning and the development of individualised movement solutions, there are still concerns on how these pedagogical approaches are enacted on the ground. In this paper, we the authors, as "pracademics", attempted to address some of the common concerns that we are aware of from our regular interactions with academics and practitioners. In brief, we highlighted some of the common challenges related to sense making concepts from Ecological Dynamics and building connections to practice. We stressed the need to invest time to think differently to create representative learning environment, rethink how assessment is to be done, finding a balance between theoretical jargon and practical application as well as intentionally situating coach development and support. We may not have all the answers, but we hope this paper could provide a useful starting point on how to apply Ecological Dynamics Theory to practice design.

KEYWORDS

ecological dynamics, practice design, pracademics, constraints-led approach, nonlinear pedagogy

## Introduction

In recent years, there has been increasing interest in pedagogical approaches that focus on exploratory learning and encouraging learners to find their own movement solutions where context plays a key role. Notably, the Constraints-led Approach (CLA) and Nonlinear Pedagogy (NLP) have garnered significant attention among academics and practitioners to explore their use in supporting skill development and adaptation (1, 2). These pedagogical approaches (mentioned above) are underpinned by the theoretical framework of Ecological Dynamics where there is an emphasis on examining and accounting for interaction among constraints to understand the emergence of movement skills (3). Not surprisingly, such ideas are intuitive to practitioners as features of "nonlinearity" during learning are easily identifiable. For example, there is non-proportional change in movement behaviours as a response to practice (i.e., sudden leaps or drops in performance), multiple ways of moving to achieve the same performance outcome, learners' responding to changes in constraints (e.g., task, performer or environmental) and the infusion of practice variability to support exploratory behaviours among learners (4, 5). With the science of skill acquisition evolving rapidly in today's

digital world, practitioners seem keen to understand more about learning with reference to these pedagogical approaches to further develop their craft.

The research surrounding Ecological Dynamics has centred on describing and explaining how pedagogy can be enacted by practitioners like teachers and coaches to account for nonlinearity in the learning process. Indeed, empirical studies have tended to focus on the impact of such pedagogical approaches on teaching, coaching and learning (6–10). Nevertheless, there is a concurrent need to gather more insights on what practitioners really think and know about pedagogical approaches based on Ecological Dynamics. For example, what is the actual translation of these ideas on the ground? Do practitioners really understand and believe in such approaches or are they blindly adopting the latest research-informed ideas? Also, what are the perceived challenges that practitioners face while trying to enact such approaches? Some critics have claimed a reluctance exists amongst Ecological Dynamics proponents to tackle the "nitty-gritty" reality of sport coaching situations (11). However, it should also be acknowledged that there is a need for good quality longitudinal data to show efficacy of these approaches. Moreover, emergence of new data types would also add opportunities to develop the evidence base. Nevertheless, the challenges of examining the efficacy of CLA or NLP serves to illustrate the complexity inherent in an ED approach. We agree that we need to hear more from practitioners working at the "coalface" to investigate how well they understand and utilise such pedagogical approaches. One important resource in this regard is to gather insights from individuals who have both academic and practical experience, otherwise known as "pracademics" (12). Hence, our aim in this article was to solicit candid insight from various pracademics to help address common concerns about pedagogical approaches based on ecological dynamics.

## Brief overview of some of the approaches based on ecological dynamics

For the sake of clarity, Ecological Dynamics is underpinned by ideas from Ecological Psychology, Complexity Sciences and Dynamical Systems Theory. It recognises the continuous interaction between the mind, the subconscious control mechanisms of the body, and the environment in learning (13). Importantly, goal-directed behaviours emerge because of the interactions among constraints, and this is a key aspect of using ecological dynamics to understand the control and coordination of the human neurobiological system (1). From CLA, the emphasis is on examining the way task, performer and environmental constraints interact with one another to shape how degrees of freedom afforded to a learner (or even group of learners) are controlled for movement behaviours to be produced to attempt to meet the task goal. Learners are constrained to find their own individualised way of moving to satisfy the interacting constraints present in the performance environment (3). NLP provides specific pedagogical design principles that support an ecological dynamics perspective to encourage pedagogical practices to promote exploratory behaviours for learners to find individualised movement solutions. These pedagogical design principles are the provision of representative learning contexts, manipulation of constraints to shape behaviours, attunement to the impact of different informational constraints that focuses on either movement form or movement outcome, emphasis on task simplification to maintain perception-action coupling and the advantage of infusing practice variability to support exploration and exploitation (3, 14). Hence NLP is a broader pedagogical approach (than CLA) that also incorporates the key principle of manipulation of constraints to guide learners. The crux of both CLA and NLP is to provide a learning environment for learners to search and exploit opportunities for actions (affordances) that can be relevant for the way these movement behaviours can be used.

Nevertheless, while there has been a lot of interest in the use of CLA and NLP in enhancing teaching, coaching and learning, there remains many questions about how CLA and NLP can be delivered at the "coalface" (i.e., on the training field, practice gym, playing field, etc.). The ideas relating to Ecological Dynamics, while arguably intuitive, are not easy to grasp for many practitioners to apply directly to the practice environment. In many instances, practitioners may have challenges in how to design practices based on the pedagogical design principles of NLP (as an example) or to formalise how CLA would be manifested as it is not easy to map the kind of dynamic interactions that would occur (15). The anxiety of not being "in control" when designing practices and therefore not being 100% sure how learners would respond to interacting constraints are real. Also, the time needed to allow for exploration may not be a luxury that many practitioners have when syllabi are to be followed and where there are certain pre-conceived milestones or learning outcomes that need to be achieved. Some may also criticise that the amount of preparations needed to enact a CLA or NLP session could be huge and not easily managed on a regular basis (14). Specifically, in the cauldron of high-performance sport where the stakes of optimal athlete preparation are so high one can sympathise with a coach for "playing it safe" and sticking with tried and trusted learning approaches rather than dabbling in CLA or NLP. Thus, there are genuine concerns about the infusion of these pedagogical approaches and the impact that it may have on learners. In this paper, we want to provide some answers or thoughts to some of the above points raised and the difficulties in showing cause and effect of intervention on learning.

## Responses to questions

For this section, each of the authors of this paper provide their thoughts on some frequently asked questions about approaches based on Ecological Dynamics.

(1) What are the struggles that practitioners may have with pedagogical approaches based on Ecological Dynamics?
(2) Why are there these struggles with pedagogical approaches based on Ecological Dynamics?
(3) Where and how does the theory come in to help practitioners support their practice?

(4) Is there a place for theory in professional development for practitioners?
(5) What are the considerations to help practitioners enact pedagogical approaches based on Ecological Dynamics to support teaching and learning? Why are these important considerations?

First, we would provide a brief overview of the background of each of the contributors.

(1) Chris Button (CB)

Chris Button is a Professor of Motor Learning at the University of Otago, New Zealand. Chris has coached football at various levels (i.e., from children, to elite, through to masters) for over twenty years. Chris is also interested in water safety education and in recent years has undertaken numerous studies and interventions investigating how best to teach children transferable water safety skills and knowledge. Chris is lead author of the textbook: "Dynamics of Skill Acquisition: An Ecological Dynamics approach" (1).

(2) Jia Yi Chow (JYC)

Jia Yi Chow is a Physical Education teacher by training, and he is currently the Associate Dean for Programme & Student Development at the Office of Teacher Education, National Institute of Education, Nanyang Technological University, Singapore. Jia Yi mentors PE teachers for Singapore schools and prepares sports science undergraduate students for the sports industry. He enacts CLA and NLP regularly in his classes and works closely with key local stakeholders in the Ministry of Education and National Sports Institutes in Singapore. He also shares his work on a regular basis with international audiences at workshops and conferences.

(3) Miriam Lee (ML)

Miriam Lee is a Senior Manager at Sport Singapore, a national agency that promotes sports and physical activity. Miriam works with early childhood educators and sport coaches from the local community to develop the fundamental movement skills of preschool children. Her PhD research was on "Nonlinear Pedagogy and its application in Singapore Schools", pursued at the National Institute of Education, Nanyang Technological University, Singapore. She continues to share and discuss ideas from Nonlinear Pedagogy through her interaction with practitioners and local stakeholders.

(4) Craig Morris (CM)

Craig Morris is an Olympic Canoe Slalom coach and high-performance coach/mentor based in London, UK. In recent years, Craig has begun to share his experiences of exploring and applying an Ecological Dynamics approach to sports coaching through academic journals and podcasts.

(5) Richard Shuttleworth (RS)

Richard Shuttleworth is the Coaching Director at Sport Singapore. He has experience leading and managing high performance development strategies, coaching and athlete development trajectories, team dynamics, in sport development and education systems in Europe, Asia and Australasia. He has also supported several successful Olympic sports campaigns at the Australian Institute of Sport (Australian Sports Commission) as Skill Acquisition Specialist spanning Beijing and London.

- What are the struggles that practitioners may have with pedagogical approaches based on Ecological Dynamics?

CB: Firstly, a challenge is to prioritise time to plan coaching sessions based on Ecological Dynamics (ED). As a coach, one should be very clear about the learning objectives of a session and how to integrate key pedagogical principles into a practice plan. I admit that I rarely spend sufficient time planning what to coach and thinking about how I should do it. Rather than follow a recipe rigidly (for practice design) I prefer to have a scaffold or some key activities which I build upon and fill in (with the learners) as the session unfolds. A common misconception is that an approach, like NLP, that is founded upon a principle like self-organisation can be done with minimal preparation. However, the more experience of coaching with ED I develop, the more I realise it is important to spend time thinking in advance how to best deliver the session, even if the product is usually different to what was planned. Similarly, once I have delivered a session, I need to more consistently note down what went well and what did not. I think I rely a little too much on memory and my perceptions for how things went, rather than systematically planning and reflecting on the process, successes and failures! Notably, one of the best opportunities for ED right now is to leverage developments in analytics, tech and performance analysis to develop systems and infrastructure to help with this.

Another struggle I continue to have is to develop strategies to involve the learner in the process of designing practice. In my work on water safety education for example, I have usually dictated what will be taught, where and when it will happen etc. I try to justify to myself that it is necessary to ensure the safety of my learners, but perhaps it is more that I am usually teaching children (approximately 7–11 years old) and I have not trusted them sufficiently to co-create an effective learning environment. I am always on the lookout for new ideas and ways to make coaching a genuinely reciprocal process and better engage the learners in practice design.

JYC: For me, the key struggles seem to be associated with understanding the language that is used pertaining to Ecological Dynamics. The term, "Ecological Dynamics", can already be daunting for a practitioner who may not have any previous idea about complexity theories and how they may support skill acquisition. This in turn leads to a lack of proper understanding of how these pedagogical approaches work in the learning context. Of course, practitioners could still use these approaches but may not be able to fully utilise what these approaches could offer. Without a proper understanding of what it means from an ecological perspective, practitioners tend to copy examples of practices designed by other practitioners who purport the use of CLA or NLP. In most instances, such copy and paste could result in less success in supporting effective skill development, which in turn, leads to frustration on the part of the teacher

or coach who is trying to use CLA or NLP. But that seems to be the typical grouse that a recipe should be provided to practitioners so that they can then replicate the lesson to achieve their desired learning outcomes for the learners. From my experiences with Student Teachers and In-service Teachers, there can be situations where they would want the "answers" to how to teach using a specific design principle but without considering that it is also situational as it can depend on the context of the learners on that day and the shift in learning outcomes for the session.

Another typical question that I get asked a lot is where the teaching of technical skills is important or if it should precede the incorporation of modified representative games in PE. My response is typically associated with what the practitioners want as a learning outcome: (i) to show the best form or (ii) to achieve the task goal in their own functional way. By asking this question, it typically sets the practitioner to start thinking about ways to achieve the outcome rather than be overly focused on the movement form (and thus an emphasis on technical skills). This inadvertently also leads to the issue of assessment and how practitioners share that they are sometimes constrained by assessment rubrics that emphasises the attainment of some expected movement form (especially in fundamental or foundational movement skills). Assessment shapes behaviours (and teaching behaviours) and thus an assessment that is focused on adaptability would be aligned to the design principles for NLP (as an example) rather than one that focuses on movement form replication.

ML: The first struggle that I often see practitioners face is absorbing and understanding the terminologies associated with Ecological Dynamics. Terms like "dynamical system theory", "complex systems", "nonlinearity", "representativeness", "affordances", "information-movement coupling" and even "Ecological Dynamics" are jargons to the common folks not familiar with the literature. They often switch off once we start to introduce such terms, and more so when we try to explain it to them. It is always a challenge to balance between simplifying it for the layperson and without losing the essence of what these terms mean.

Another common struggle with practitioners working with young children is coming to terms with the notion that "there can be more than one way to achieve a task goal". When it comes to teaching and learning gross motor skills or fundamental movement skills (FMS), there is a tendency still to hold on to traditional approaches in which the objective is primarily to achieve a predetermined criterion movement form. This is especially the case for sport coaches where practice sessions often involve drill-like and prescriptive instructions, despite efforts to share with them about exploratory pedagogy approaches.

As for the early childhood educators I work with, most seem open to ideas from Nonlinear Pedagogy such as letting children "explore and discover their own functional movement solutions". Afterall, the preschool years are about exploration and discovery of themselves and the world around them. The part practitioners find hard to reconcile is the way a child's movement should be observed and assessed. Questions such as "If I don't use a movement checklist, then how do I know how well my child is progressing?" often emerge. On my part, I am constantly on a search to find alternative ways of observation/assessment aligned to pedagogical approaches based on ED, but it still has been a challenge to find tangible solutions that satisfies the needs of these practitioners.

CM: A struggle I have witnessed relates to answering the question of efficacy regarding an Ecological Dynamics approach in a society that values linear causality abstracted via metrics of progress and performance based on predetermined "fundamentals" of a sport. Metrics that are often sought in tasks undertaken in impoverished environments and/or supported by "evidencing" a growing knowledge about a specific technique, play or discipline through the spoken word. Amidst systems/cultures that prioritise hierarchies, prescription, control and predictability to forecast future success and showcase return on investment, an ED practitioner can face a struggle in aligning with what is seemingly valued by vast swathes of sporting domains.

Shaping affordances with integrity to a nonlinear approach is often a source of struggle for coaches. Designing tasks to explore new invitations for action without over constraining them, and thus losing representativeness, can be a real challenge. This requires the coach not only to have a clear understanding of theory but also to go through a process of "letting go". This may involve letting go of answers they already have to leave multiple possibilities open that are likely more representative of the task itself during competition. Indeed, the use of "radical constraints" that narrow the field of affordances so much that perhaps only the solution the coach wants is available, is in my opinion little different to verbally solving a problem for them. We must ask ourselves are performers merely meeting the knowledge of the coach rather than exploring the thing itself? Perhaps, this is where they may learn that something works after exploration (e.g., experiencing success to meet task outcome). The understanding of why it works could come later upon reflection or further discourse with a mentor or peers.

RS: Coaches may have trouble learning about the use of constraints and CLA. It is a challenge to engage fully with "CLA", but some coaches manage by "flirting" with the approach and applying a degree of pragmatism instead of "marrying" totally to it. Others suggest it gives them tools to explore within their practice but also a chance to understand why and how so that they can create their own applied frameworks. For example, a coach I know experienced his biggest breakthrough when he explained how ED opened his eyes to seeing the value in opportunities on a macro and micro level, thus helping him to create a new bottom-up individualised curriculum (needs-based solutions) for swimming. It helped guide the way he viewed how a child could optimise learning using an aquatic environment (i.e., macro level) to focus on saving lives from drowning and promote health. In this case, competitive swimming is therefore not representative of the task and more work was needed changing the environment and experiences. On a micro level in performance swimming, he was able to switch his attention from energy systems, and prescribed volume-based training to a skills focus. Both frameworks side by side looked similar but the difference was the intention. Training energy systems could

neglect skill but training skill he assured me, also trains the energy systems. This could be an example of the knowledge of the environment, supporting better adaptation to the world around us and thereby optimising performance.

In addition, facilitation and guidance, practitioners can usually acquire strategies to transfer ED language into their own "action-based terms" and simplify (e.g., generally affordances become opportunities, self-organisation is adapting, attractor behaviour are tendencies etc. However, original meanings are usually lost in translation and can often be corrupted through cognitive biases).

- Why are there these struggles with pedagogical approaches based on Ecological Dynamics?

CB: Time is limited, and the digital world provides so much information for practitioners that the fundamentals of the process (like planning, reflection, co-creation, etc.) may be overlooked. Seductive concepts like life-hacks and You-Tube clips offer practitioners a plethora of potential shortcuts to bypass the dense academic literature and search for quick and ready answers to their problems. However, I tend to feel most satisfied as a coach if: (1) I have taken the time to take some notes before and after a practice session; (2) I have listened to learners and adapted my session to better suit their needs, and (3) myself and the learners were engaged, focussed and challenged by the activities we co-created. Perhaps because ED does not typically provide detailed instructions for coaching (a recipe book style), some may be challenged to put in the background work required to apply the principles successfully. This calls for incorporating interdisciplinary teams to support the use of such approaches.

JYC: There are probably a few reasons. It is possible that these terms may not have been explained properly to practitioners or in a way that is too technical that, without adequate prior knowledge about the theoretical concepts, could lead to confusion in understanding what CLA and NLP represents. Or, in other instances, the prior knowledge may be superficial (i.e., knowing the terms *per se* but not really what the concepts mean and how it would impact practice design) and thus there is a lack of clarity in how the ideas are utilised. In other occasions, the teachers or coaches may still follow quite a top-down or prescriptive perspective to how they think designing a practice could entail even though they may consider CLA and NLP as an intuitive approach to account for individualised learning. These practitioners may find it difficult to "not be in control" and allow for students to explore. Letting go of control would seem to be the hardest thing to do even though it seems to be the right thing in their mind. Thus, they may then resort to copying and pasting learning activities that they know worked when demonstrated by others.

ML: In my opinion, there are several reasons associated with these struggles. Firstly, it takes time to make sense, ask questions, try it out, but there is not always the luxury of time for this self-discovery process especially for practitioners who have competing demands. In some instances, academics continue to use abstract terms and examples to explain, making it hard for those not familiar with the language to understand and relate to. Most importantly, coaches and educators need practical examples to help them see how it is implemented and reassurance that ED pedagogical approaches work in practice for the early years. While online material such as FMS activity videos are readily available, many of these resources point towards learning FMS in isolation and fail to take into consideration the interaction that occurs between the learner, environment and task. Another reason why coaches may choose not to adopt ED approaches could be associated with the expectations from parents and others around, especially for paid programmes. For example, a coach once shared how he agreed with this approach, but he was hesitant to implement as parents may complain if it looked like he was not teaching and if the class looked messy. Perhaps, it would have helped if a clearer communication of the approach up front to the parents could clarify any misunderstanding on why the session was conducted in such a manner. Last of all, adopting an ED pedagogical approach requires a mindset shift for most practitioners, and if most of society do not embrace it, then it is probably easier for them to stick to old ways for the moment.

CM: The focus of study for the Ecological Dynamics practitioner is the reciprocity of the performer-environment interaction. Hence, attributing the efficacy of any one intervention or component of that interaction upon progress and performance in a causal linear fashion that is craved by many organisations is incompatible with the approach. Resultantly, the ED practitioner may find themselves unable to show cause and effect of their coaching in a way that is valued by their key stakeholders (club, programme, federation, parents etc). This can in turn leave them in a vulnerable position, often facing feedback regarding a perceived dereliction of duty or negligence by those who conceptualise the role of the coach in a starkly different manner. To exemplify, ecological approaches situate the role of the coach as an environment designer, problem setter and guide by the side, coaching interactions above actions. In contrast, the common societal conceptualisation of a coach is more as a gatekeeper of knowledge who disseminates expertise to performers from a hierarchical position through what and how of problem solving via technical models, set patterns and verbal instruction. Consequently, if progress is assessed in dualistic terms of performer as a separate entity to the environment, then the impact of an ED practitioner's work may well not meet expectations of their stakeholders.

RS: Applied sport coaching practice is often guided by a scientific approach, manifested in models or frameworks, which are viewed as the preferred or only way to facilitate athlete performance and development. This position can be problematic because the constitution of scientific knowledge has little meaning when attempts are made to apply it (i.e., a coaching approach) without consideration of context, people, and settings. It can be argued that such Ecological Dynamics frameworks for coaching have not been developed in partnership with coaching education, coaching process and applied practice design and as such are stand-alone models or frameworks that espouse an alternative approach to normal coaching and endure similar criticisms to more outdated approaches (i.e., new way vs. old way).

The issue is further exacerbated by the polarisation of athlete and coach learning, where all too often these two domains

are reduced to separate entities evident in traditional coach education and athlete development practices. A concern with approaches (to coaching) is that what was once a good idea on how to describe and explain how skilled behaviour emerges can quickly become a coaching ideology where there exists a need to promote and defend a viewpoint/theory giving rise to a doctrine or a mutually exclusive approach claiming prominence. Ability to elicit the emergence of skilled behaviour over time risks being marginalised or even disregarded in favour of a new alternative. Rather, experiencing a buffet of learning principles that can be tasted and applied to coach-performer interactions in context (co-adapting menu).

- Where and how does the theory come in to help practitioners support their practice?

CB: Theory is the foundation upon which good practice is built. It provides a solid and reliable base upon which practitioners can design learning experiences. When it is most effective, theory sits in the background "unnoticed", but practitioners can continually refer to it for guidance and reassurance. Powerful theoretical ideas such as self-organisation and affordances help practitioners to continually monitor and question their activities (and assumptions about learning).

JYC: In my view, there is a tendency for practitioners to use approaches that intuitively work for them or if they believe that the pedagogical practices used are "tried and tested". Thus, they may be able to know the "what" or even "how" to teach/coach but may lack the understanding of the "why". Is this important to know the "why" of what they do? I believe understanding why they design learning tasks in specific ways would give them greater adaptability in adjusting their practices to meet the needs of the learners. Consider the point on differentiated instructions where a practitioner can have the adaptability to skilfully manipulate constraints to challenge different learners in a class or practice session differently according to your competencies and needs. With a deeper knowledge of theory, a practitioner will then have more flexibility and understanding on how their practices can be designed purposefully.

ML: The theory provides a framework to guide practitioners to design and deliver practice sessions that are child-centred and meaningful for individual learners. Having a sound understanding of the theory will give practitioners a better appreciation of ED pedagogical approaches and to be in more control in varying situations: To be able to modify activities according to learners' needs, co-create activities, and to embrace unpredictability that occurs in learning.

CM: Theory has played a pivotal role in shaping "why I coach the way I coach" whilst also enhancing confidence in my approach. Furthermore, it has invited me to co-create this "why" with athletes, sharing our perceptions of what the sport is and reflecting upon how congruent our practice methodologies are in preparing for skilled performance in competition. In essence it is an anchor of reference for practitioners in the loop of "observe to design, design to observe". As in an ED approach, a role of the coach may be guidance without specification toward information that could invite skilled action, so too theory guides the attention of the practitioner. For example, in my own practice, my attention is now guided toward affirmation of skilled adaptability by athletes, where once I saw movement variability as an error in the pursuit of consistency and repeatability. Theory therefore may be viewed as a companion or co-coach supporting our own decision making and development as we too seek to support the decision making and development of others.

RS: There exists a need for an experienced facilitator who can develop trust and a caring relationship that allows him/her to elicit a coach's existing perceptions, views, beliefs (i.e., intrinsic dynamics) and begin to question key assumptions in a safe, open yet uncertain environment. This is before any imparting of new knowledge which often will contrast and may even conflict with any stable self-held viewpoints and explanations of how human behaviour emerges [i.e., emergence (radical emergence) competing with the concept of design for learning foundational and skilled movement]. With practitioners, over time terminology can become normalised, easier to understand and more relevant to their ability to improve an individual's performance capabilities. If the practitioner possesses a natural interest and is motivated to pick up knowledge and acquire an understanding of ED, they become more motivated to establish deeper personal interpretations and meaningful connections rather than making mental representations and comparisons between approaches which is more often the case in coaching education pathways.

- Is there a place for theory in professional development for practitioners?

CB: Practitioners can operate and develop themselves in the absence of a theoretical model of the learner, indeed many have done that. However, "professional development" infers that practitioners are systematically preparing themselves to operate at a high level. In such a case then theory informs evidence-based practice and has a valuable place in a practitioner's toolbox. Whether it is coaching a junior football team or a national league futsal squad, I have found reassurance in my own professional development that has been informed by scientific theory.

JYC: There is certainly a place for theory in professional development for practitioners in my view. The above point about having theory support practice is key to enabling practitioners go beyond just trying to find "suitable" activity plans and re-enact them. Practitioners must go beyond the "copy and paste approach" of delivering practices as this would not adequately account for the dynamism that we would observe in all teaching and learning contexts where learner-environment mutuality is inherently present. It is important for practitioners to know why they are designing their practices in a specific manner.

ML: Yes, theory is an important part of professional development as it provides the basis for learning new skills and knowledge. Nonetheless, theory needs to be presented together with practical examples to help practitioners make sense of it and eventually apply their own context. As part of professional development, practitioners also become learners themselves during which learning takes place through interaction, adaptation, and co-creation of new knowledge between the

facilitator and other learners in the environment. When practitioners can understand that they too are part of a larger system that involves the interaction of constraints, they will be in a much better place to apply theory into practice.

CM: In my experience, yes for both practitioners and performers. Theory acts as a constraint upon coaching practice, guiding attention from the infinite possibilities for practice design and interventions that can create a random experience that confuses athletes. With a shared theoretical approach practitioners and performers have a coordinated approach to why they practice the way they practice enabling co-adaption with an anchored reference point amidst what is inherently a dynamic journey.

RS: There is a place for theory, but some considerations need to be taken. Experience suggests it is likely not the terminology that is the issue but the simplification of the terminology that needs careful attention. Understanding IN action makes for coaching IN moment (e.g., immersion or entanglement) and coaching the performer (not the curriculum/learning outcomes) a more authentic (i.e., coach interaction fidelity) transformational experience when supporting a coach in navigating their development journey through a particularly unforgiving paradoxical landscape (e.g., learning and performance exclusivity or mutuality).

- What are the considerations to help practitioners enact pedagogical approaches based on Ecological Dynamics to support teaching and learning? Why are these important considerations?

CB: Learning can and does happen, with or without, practitioners. A key consideration for practitioners is their curiosity or appetite to "understand" and thereby potentially facilitate the learning process. Practitioners can choose to be passengers (i.e., passive) in this journey of understanding or they can equip themselves to augment the trip and become active partners alongside the learner/s. In my experience, important considerations are the extent to which the skills that are practiced are retained over time, are transferable to other contexts, and finally are stable in the face of a change in constraints. Personally, I think Ecological Dynamics is unique (in contrast to other theories of motor learning) in its ability to support each of these considerations when co-designing and reflecting upon practice. In addition, we could also incorporate the use of technology to better capture the learning experiences, which can show the value of an ED approach.

JYC: The biggest challenge is the fear of "letting go" on the part of the practitioner. There is typically a strong desire to prescribe how learning should exactly occur for the learner which leads to a teacher-centred approach. The practitioner prescribes instructions that dictates the expected movement form expected from learners without accounting for individual differences in the learning context. There is a need to be the holder of knowledge and experience on how learning should be undertaken. Thus, it would need a mindset change on the part of the practitioner to be "comfortable being uncomfortable" to let learners explore their own movement solutions to accomplish task goals set out in the session. Without holding prescriptive informational constraints to tell learners exactly how to solve a movement problem is something that practitioners may need some getting used to.

ML: To bring practitioners along with us on the journey, we need to help them relate to ED pedagogical approaches in the first place. For example, by using language that the target practitioners can identify with, we may be able to unlock their interest and open the door for further conversations and discovery of a deeper understanding of this approach. Besides the practitioner, others in the ecosystem also need to be educated about this approach. They need to understand and be aware about the nonlinearity that may emerge during practice sessions. Parents, senior management, and others in society need to be on the same page and support this approach for practitioners to successfully implement it.

CM: Support on the journey toward an embracement of uncertainty, of letting go of "knowing" and the idea of controlling what we can control in favour of immersing ourselves in the actual goings on of things. This may not be a shift of simply one individual but may indeed be an entire organisation, as constraints of the system act upon a practitioner (e.g., viewing coach as a hierarchical position and prescribing learning) and can therefore inhibit invitations to act in a way that supports an ED approach. To exemplify, coaches need support to pacify a perception that they need to have a prescribed plan for practice design and that it needs to be right first time. As with athletes, coaches must be given and give themselves permission to explore, to iterate, and to understand that development is nonlinear and thus what works in one context at one time may not necessarily work on repeat.

Secondly, sharing the journey into ED is in my opinion critical. Not in a sense of taking people with you but rather co-creating and adapting on a direction of travel. It is in my experience important that practitioners remain authentic when considering a pedagogical shift. A big part of this is to share "why" with performers and colleagues and invite feedback and challenge. Indeed, without explanation such approaches can be viewed incorrectly as "hands off". Hence, we must acknowledge that an ED approach is significantly different to mainstream conceptualisations of coaching and therefore if enacted without explanation of why to stakeholders, then we are likely to be swimming against the tide.

RS: While ED can be challenging to one's view of the world, it also allows for thoughts to be dynamic, as opposed to being fixed, explicit or requiring a process. Some coaches find this freedom of thought both in and outside of sport and coaching context to be self-empowering and helps them make deeper connections to the wider world and sense making. A surfer finds that each wave is different, and they can only act upon what the wave offers. Therefore, a mutual respect between them and the environment is created. That said, the coach is aware that when they coach sport and they are outside of their comfort zone, they resort to the explicit direct approaches to reassure themselves that they are missing anything. Repeating the technical knowledge to show apparent competency. Within the realm of exploring ED principles of learning, coaches can become more relaxed in their approach and recognise the "knowledge about" has now been replaced by their search to discover the knowledge (information within) of, just like the waves taught (invited) the coach which parts to surf.

## Further implications and considerations for the adoption of pedagogical approaches based on ecological dynamics

Based on the input and candid sharing by the co-authors of this paper, we hope the discussion has provided helpful insights to the reality of practising pedagogical approaches based on ED and certainly the challenges that we (and you may) have faced as well.

### Investment of time, thinking differently and creating representative learning designs

One common theme has been the necessity of investment of time for forethought, planning and co-creation of practice. In a digital world where quick solutions are available "at our fingertips" this investment of time is a real, tangible barrier that may force many practitioners to shy away from these approaches. Also, we have identified that an "open mind" is required from practitioners to expose themselves to theory, to try new things, and to emphasise adaptability of skill-learning are crucial elements of successfully utilising such approaches. Undoubtedly, ED forces practitioners to think quite differently about the learner and the learning process and we acknowledge that it takes some courage and patience to turn away from strategies that may have remained unchallenged for decades. Another theme that emerged from many of our answers was the idea of how to best represent performance characteristics in practice environments. Whilst the concept of representative design was introduced quite some time ago (i.e. (16), it has only quite recently made a long overdue entrance into the motor learning literature (17). As practitioner's ability to modify and simulate learning environments continues to grow rapidly, this is one issue which will capture our attention in the years ahead.

### More than just manipulating constraints

CLA is a framework that describes how humans self-organise movement solutions through interaction with the environment. Therefore, technically all coaching is constraints led. This does not mean of course that it is informed and anchored by a theoretical framework that aids a coach's observation, decision making and correspondence. In an Ecological Dynamics approach to sports coaching, it is the key principles of a Nonlinear Pedagogy that underpin a CLA, informing the decisions we make as coaches on the why, what, when and how of constraint manipulations (3). Principles such as representative learning design, repetition without repetition and perception-action coupling guide skilful use of constraint manipulation which enhances the chances of development and transfer to competition. Designing practice environments therefore is not about manipulation to guide performers to the coaches pre-determined solution but to ease the grip on preconceived ideas to pay genuine attention to the individuals search for solutions (18). This process is challenging when we genuinely want people to progress and the temptation to shortcut through heavy signposting to solutions can be strong. Here an understanding of underpinning theory can give a coach confidence, opening one up to new possibilities for action through the creative exploration of performers. Afterall sport can only move forward if we stop simply trying to replicate what has gone before.

### Let us find a balance between theoretical jargon and practical application

But there is certainly a need to find some balance between theoretical jargon and practical application of knowledge. Ecological (psychology) and dynamical (systems) evolutionary language describing Ecological Dynamics is often a confronting barrier for curious coaches to explore further. This can be exemplified through futile attempts to link coach-performer interactions to relevant theoretical ideas and underpinning principles unless there is an experienced theoretically informed practitioner (e.g., pracademic) or coach developer.

Coaches have suggested simplifying the language and helping them to find a grounding position to see the landscape in front of them. For example, a coach only saw complex pieces of the swimmers' physiological demands and the complex scientific needs. However, when he scaled back his thinking and looked carefully at the landscape of pool affordances, it became clear that the sport required very simple demands of reducing drag and increasing propulsion. From here he then built up his philosophy and appreciation of the skills needed to be performed under physical and psychological pressure.

### But what about assessment?

Methodologies of assessment of an approach must be congruent with the approach itself, namely how the performer interacts with the environment that is representative of the performance context. Such assessments are inherently complex and rarely offer the certainty desired by those conducting them hence ED practitioners are often judged by results only. Given a nonlinear approach is a performer centred, long term approach to skill development, then in certain climates this gives the coach little time if results are not considered adequate in the short term (14). Thus, coaches can be left feeling vulnerable, isolated and without the relevant permissions to explore. It is possible they may lose their job before the impact of their work has time to show or perhaps the perceived needs of the coach to conform to pervasive societal views of what a coach is and what a coach does may begin to dominate their practice above the needs of the performer(s). A range of assessment methods that acknowledge exploration, sensitivity to affordances, and adaptation to constraints are much needed for the practitioner's toolbox.

### Situated coach development and support

As ED positions performer (and coach) performance and development through the conceptualisation of an ecological learning system (19), where performance problems and subsequent solutions emerge from the moment-to-moment interactions between coaches, athletes, scientific principles, and contexts. Therefore, learning is not assumed to occur based on a

predetermined model or framework, rather, learning is situated within dynamic, context dependent, and lived experiences of athletes' and coaches (20). Coaching, and therefore athlete learning happens *in* the moment, to elicit more contextualised, evolving, and adaptable interactions related to context. Rather than through a model or framework that has a definite start and end point (e.g., *plan, do, review*), reliant on memory-based post event reflections that can place the coach under pressure (e.g., peer, leadership, parental, and organisational etc) to appease apparent perceived need for more established traditional practice methods of learning and performance outcomes. The constellation of key actors in an ecological learning system can support the contextualisation and individualisation of athlete, coach, learning and development. Importantly, there could be greater emphasis on supporting coach education centred around acquiring knowledge of the environment (direct perception). Approaches based on Ecological Dynamics can promote continuous self-regulation of learning on the part of the coach and teacher so that the practitioner can explore and attain a better fit with the performance environment (21).

## Conclusion

We realise that many of you might also find yourself disappointed if you expected a detailed recipe of how CLA or NLP can be enacted from this paper. However, as we have explained, such pre-determined and mechanistic solutions are counter to the theoretical assumptions that underpin the ED approach. Instead, our aim was to encourage you to shift your mindset (away from concepts like prescription and standardization) towards practices that emphasise and support adaptability. Finally, we humbly recognise that we do not have all the answers to many of the important questions that have emerged with the development and uptake of these ED-informed approaches. It is indeed an on-going journey for us all as we continue to embrace exploration in teaching, coaching and learning.

## Data availability statement

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

## Author contributions

JYC and CB: conceptualised the paper. All authors contributed to the article and approved the submitted version.

## 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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# Every story has two sides: evaluating information processing and ecological dynamics perspectives of focus of attention in skill acquisition

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Directing our focus of attention appropriately during task execution can benefit outcome performance, cognitive efficiency, and physiological efficiency. For instance, individuals may benefit from adopting an external focus of attention (i.e., by focusing attention on the effects of one's movements on the environment) over an internal focus of attention (e.g., focusing on one's body movements). However, accounts concerning the theoretical functioning of such effects have primarily relied on hierarchical information processing perspectives; far less consideration has been given to potentially alternative explanations based on ecological dynamics, instances where an internal focus may be desirable over an external focus, and the associated applied implications. Within the present review, we: (a) outline the most recent developments in attentional focus research; (b) evaluate similarities and differences between information processing and ecological dynamics explanations of the focus of attention effect; (c) provide practical recommendations; and (d) discuss future research avenues. In doing so, a case is made for an "Ecological Dynamics Account of Attentional Focus" to act as an alternative to information processing-based hypotheses.

KEYWORDS

sport, attentional focus, movement, cognition, dynamical systems, motor learning

## Introduction: the focus of attention phenomenon

Verbal instruction is one of the most common methods of conveying information to individuals when learning and performing motor skills. However, it is now well established that the language we use when providing instruction can influence the skill acquisition process, particularly in relation to whether it directs an individual's attention internally towards the body or externally towards the effect of one's movements on the environment (1). This phenomenon is consistent with early rhetoric from James (2) when discussing the influence of attention on movement outcomes: "Keep your eye at the place aimed at, and your hand will fetch the target; think of your hand, and you will likely miss your aim" (p. 520). There is now a wealth of literature supporting an external focus of attention for several performance outcomes; including accuracy, speed, cardiovascular endurance, maximum force production, movement kinematics and motor economy [for reviews see (1, 3)]. Benefits of an external focus also extend beyond sport and have been applied to enhance movement solutions within varying domains, including the military (4) and healthcare fields. Examples include when working with Parkinson's (5), stroke (6), or multiple sclerosis patients (7), as well as those with intellectual disabilities (8), in older

populations (9), requiring falls prevention (10), and in rehabilitation environments such as individuals recovering from ankle sprains (11) or ACL reconstructive surgery (12).

However, accounts concerning the theoretical mechanisms underpinning such effects have primarily relied on hierarchical information processing perspectives, whilst far less consideration has been given to alternative explanations based on ecological dynamics and the applied implications thereof. There remains debate in the skill acquisition field with regards to the extent to which end-uses of theory (i.e., practitioners such as sports coaches) should comprehend the theoretical underpinnings of skill learning so that they may best align practice decisions with their chosen perspective. Philosophically, if we adopt a "shed-building metaphor": one belief is that if you build a shed in your garden, whether you believe the earth is flat or spherical, has little influence on the way in which the shed is built. However, there should be little doubt that for the best practice conditions to occur, coaches must be able to justify their decision making and articulate the rationale underpinning applied practice decisions. This has implications on coach education, where adequate skill acquisition and pedagogical training is arguably sporadic on a global scale (13).

The present review aims to address these issues by providing greater clarity in relation to the fundamental theoretical principles underpinning differing perspectives that account for the focus of attention effect within skill learning/performance, and aim to address implications for applied practice. More specifically, the review will: (a) outline the most pertinent developments in the attentional focus literature; (b) evaluate similarities and differences between information processing and ecological dynamics explanations of the focus of attention effect; (c) provide practical recommendations and suggestions for coach education; and (d) discuss future research avenues. In doing so, a case is made for an Ecological Dynamics Account of Attentional Focus to act as an alternative to information processing-based hypotheses.

# Recent research directions

## Focus distance

When selecting appropriate external foci, some contexts require practitioners to decide between multiple alternatives. For example, a hockey coach choosing to direct attention towards the club vs. the ball, or a medical doctor choosing to attend to their scalpel vs. the target epidermis. This conundrum has led researchers to investigate "the distance effect", whereby benefits of distal external foci (i.e., environmental/task information far from the body) over proximal external foci (i.e., environmental/task information close to the body) were first identified by McNevin et al. (14), on the basis that attending to external movement effects further from the body are more easily differentiated from the body and thus more likely to facilitate automaticity. At first glance, this finding seems robust across experts and novices (14–16), but more recently, Singh and Wulf (17) have reported some interesting nuances. Whilst the authors provide further evidence to support a more distal focus for the expert performer, for tasks that require coordination of greater degrees of freedom (e.g., a snatch in weightlifting), then it is argued that a proximal external focus that is better aligned with technique, may be more appropriate for novices. Differential findings as a function of expertise were also supported with measures of focus preference (i.e., experts preferred a distal focus and novices more proximal). Singh et al. (18) have accounted for these findings with the notion of functional variability when distality of focus is appropriately matched to expertise level. The authors showed evidence for enhanced coordination of the shoulder, elbow and wrist in a volleyball serve, for skilled performers adopting a more distal as opposed to proximal focus.

Interestingly, the distance effect has also been considered in the context of an internal focus. Pelleck and Passmore (19) investigated a range of performance metrics when adopting an internal attentional focus more proximal or distal to technical features of the task. The authors hypothesised that the detrimental effects of an internal focus would be exacerbated when more proximal to critical elements of the technique, by crating greater interference with automatic self-organisation thereof. Indeed, in a golf putt, measures of movement accuracy, muscle activity, and kinematics were all adversely affected when directing attention proximally towards technique-relevant upper-body as opposed to distally towards technique-irrelevant lower-body limb mechanics.

## Focus relevance

Findings from Pelleck and Passmore (19) suggest that any disturbances to the motor system when focusing internally, may be concentrated towards more skill-relevant bodily factors in tasks otherwise reliant on environmental afferent information. It is conceivable that focusing internally on limb mechanics which are responsible for action (e.g., upper-body in golf) may be of least task relevance in far-aiming tasks, since the motor system is capable of self-organising limb mechanics without a need for conscious monitoring [see also (20)]. In this manner, it is possible that focus relevance may moderate the relationship between expertise and focus distance (17, 21). Indeed, Amini and Vaezmousavi (4) reveal enhanced shooting performance in elite military personnel when adopting a more task relevant external focus (regardless of distality) [see also (22)]. An external-relevant focus which comprised mentally focusing on the target facilitated superior shooting performance compared to an external-irrelevant focus which comprised focusing mentally on a randomly presented auditory stimulus to judge its bass and treble. Therefore, relevance of the external focus to the task may be a key consideration when formulating instruction.

## Focus salience

With focus relevance intricacies in mind, recent research has emphasized the complexities of selecting appropriate external foci for learning and performance. Mechanistic explanations underpinning the attentional focus phenomenon have tended to emphasize the role of an external focus to augment congruence between planning and action, and ultimately enhance automaticity

of motor programming (see Wulf et al.'s (23)], constrained action hypothesis, and Wulf & Lewthwaite's (24, 25) notion of goal-action coupling, respectively). However, it stands to reason that these mechanisms rely on there being a more tangible (i.e., relevant) movement effect such as motion of a club, racket, or ball. In the absence of this, Lawrence et al. (26) argue that the benefits of an external focus may be diminished. Whilst there remain some inconsistencies in the literature when investigating this type of form task [see also (27)], there is little doubt that from a practitioner perspective, some tasks may exhibit challenges when identifying more salient external movement effects e.g., within floor gymnastics or dance. More recently, Becker et al. (28) present a novel solution to such instances, via a holistic attentional focus that is targeted towards generalised feelings of the movement to inhibit conscious control of effectors. When tested in a standing long jump, findings revealed that both an external and holistic focus enhanced performance, with no statistical difference between the two. Becker and colleagues advocate a holistic focus when an external focus is neither practical nor desired. A similar solution which adopts what the authors term a "mind over body" approach, entails replacing body parts (in this instance, the supine forearms in a volleyball pass), with the depicted image of an external object (a "platform") (29). This shows promising findings and is consistent with more traditional implicit learning techniques such as analogy learning (30).

## Wider psychological mechanisms

Irrespective of nuances surrounding the distance effect and skill relevance, the literature to date presents a robust representation of the attentional focus phenomenon, and benefits of an external focus. However, this literature has typically considered the relationship between small numbers of variables in isolation, for example the influence of an external focus of attention on electromyography (EMG) or movement amplitude, somewhat removed from interactive psychological functioning (see 1 for a review). These linear methodologies have justifiably been adopted in the name of conserving methodological integrity and rigour. However, a more recent research direction has begun to embrace more holistic and non-linear methodologies, arguably more consistent with skill acquisition in practice. In this manner, Wulf and Lewthwaite's (24, 25) OPTIMAL theory (optimising performance through intrinsic motivation and attention for learning) (see **Figure 1**), proposes that learning is a consequence of interactions between both attentional and motivational factors. The authors speculate that the ideal sensorimotor and motivational conditions can lead to enhanced goal-action coupling via use of more efficient functional connections across brain networks. Specifically, learning environments which promote autonomy (e.g., choice in the training activity undertaken) and enhanced expectancies (e.g., belief that the training activity will benefit performance) should increase dopamingergic responses and engagement with the task, which when combined with an optimal external attentional focus direction, enables individuals to achieve greater neural coupling between the task goal and action being organised. Therefore, wider psychological mechanisms may be a valuable consideration in focus of attention literature and applied practice going forward.

## Ecological validity

The shift in research direction to investigate the attentional focus phenomenon more holistically, has also cemented a need to test in in more ecologically valid environments. Despite an extensive

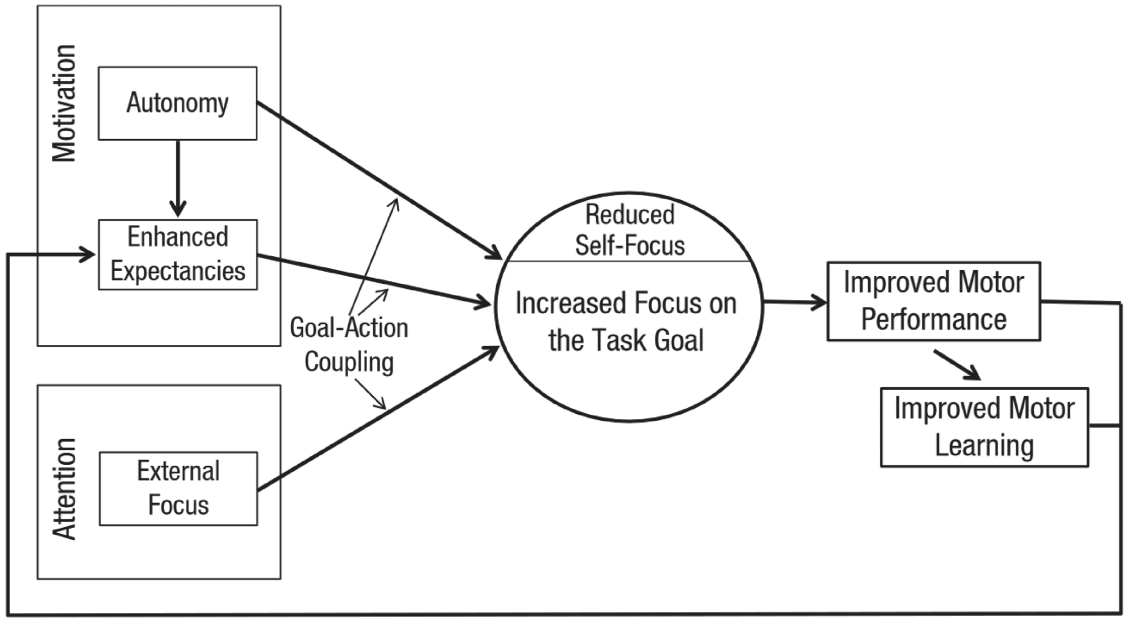


FIGURE 1
Schematic depicting Wulf and Lewthwaite's (24, 25) OPTIMAL theory of motor learning.

literature-base supporting the robustness of an external focus of attention to enhance a breadth of movement outcomes (see 1 Wulf, 2013), the field has arguably failed to bridge the gulf between theory and practice. There remain significant discrepancies between what is advocated by empirical research and the language being observed from coaches and practitioners in the field (31). Research methodologies embracing the value of investigating attentional focus in more "naturalised" environments, are likely to give us a better understanding of the "what, when, why, and how" of different focus instructions and strategies, and subsequently identify why these discrepancies exist so that we might ensure efficacy of coach education. Whilst several studies have now adopted observational approaches to identify the nature of attentional focus instructions and strategies employed in sport and rehabilitation environments [e.g., (32–35)], richer qualitative approaches [e.g. (36)], have advanced this further to: (a) explore the functionality of different focus instructions across both practice and competition environments; (b) investigate differences in attentional focus across different aspects of the game i.e., the short vs. long game; and (c) identify the mechanisms influencing adoption of attentional foci, e.g., self-generated vs. coach-led instruction. Findings highlight the complexities underpinning the attentional focus phenomenon and likely account for discrepancies between research and practice. For example, whilst coaches had a role in influencing the attentional focus adopted in elite-level golf, there was a lack of consistency between the attentional focus advocated by coaches and what was adopted by players in practice and competition. Furthermore, the attentional focus adopted by players varied between the short- and long-game, with players more likely to focus on the body during the short-game, and focus during competition environments typically being self-generated by players as opposed to coming from the coach. Isolated coach education interventions are therefore unlikely to be sufficient in enhancing the extent to which an external focus is employed during practice environments.

When investigated in more ecologically valid settings with athletes, Anderson et al.'s (37) findings are consistent with the notion that the attentional focus effect is likely more complex than is currently portrayed by the literature. The authors adopted machine learning techniques to identify patterns of attributes that differentiated between two groups of athletes: high and low performing Olympic weightlifters. Associated odds ratios revealed that athletes were 9.5 times more likely to achieve high-performing status if they had completed over 281 h of practice using an internal focus of attention by the first phase of testing. It is important to note however, that whilst this was the case, athletes were also 9.3 times more likely to reach the same status if they had completed over 346 h using an external focus of attention by the same stage. Together, these findings suggest that different types of focus instructions might possess different functions during an athlete's development.

## Facilitative somaesthetic awareness

Similarly to the complexities associated with ecological settings, the purpose of focus of attention prescription also appears to play an important role in determining optimal attentional foci. Toner and Moran (38) propose a functional "somaesthetic awareness" for correcting bad habits. They advocate switching between what they term more reflective (internal) and unreflective (external) modes of bodily awareness, the same way in which an athlete might switch between the autonomous and associative phases of learning (39) when making adjustments to problematic movements that would normally be executed outside of conscious control. This is also consistent with Carson and Collins' (40–42) non-linear Five-A model of technical refinement [analysis, awareness, adjustment, (re)automation, and assurance], wherein the process of skill refinement is differentiated from that of skill learning. The second stage of the process centres around "awareness" with the authors arguing that the skill must be "de-automised" prior to technical corrections being made. More recently, Gottwald et al. (43) suggest that an internal focus (or somaesthetic awareness) may also have value when congruent with afferent information more useful for task success e.g., proprioceptive tasks such as artistic gymnastics. This was tested over a series of three studies using upper and lower limb extension tasks, where pertinence of proprioceptive information was enhanced by removing vision or adding weighted objects to limbs involved in movement production. Enhanced movement economy via reduced EMG activity was consistent with outcome measures of performance accuracy when adopting a congruent internal focus. These findings warrant further investigation in more ecologically valid tasks but may account for the incongruous findings in Olympic weightlifting (37), where proprioception is arguably integral to successful movement execution of the snatch and clean and jerk. In a similar task, Kal et al. (44) also revealed trends supporting enhanced automaticity for stroke patients when adopting an internal focus. The authors accounted for these findings with the notion that this population may have preferred using an internal focus in daily life, perhaps strengthened by familiarity as inferred from Collins et al. (45).

This notion of a facilitative somaesthetic awareness is also supported by Moore et al. (46), who investigate the value of using different attentional focus prompts in rearfoot-striking runners, to correct problems in their gait and achieve a flatter foot at ground contact. An internal focus was shown to be more effective for retraining kinematics with no detriment to physiological responses. Similarly, Schücker et al. (47) showed that focusing on the feeling of the body in endurance running did not disrupt movement economy if the focus was not directed towards a highly automated process such as breathing. This has implications for use of an internal focus for pacing. Similarly, Neumann et al. (48) have revealed benefits of an internal focus in rowing where performance outputs were not constrained. Participants focusing on a series of internal vs. external cues, showed performance benefits via distance rowed, power output per stroke and physical exertion. These complexities are consistent with the notion that internal and external foci might be more appropriate for different functional roles. Recent evidence (49, 50) suggests that switching attention between movement preparation and execution might benefit performance. This is also supported by Gottwald et al. (43) who identified

benefits of an internal focus for motor planning, but not control, in proprioceptive tasks.

## Focus of attention from an information processing perspective

Accounts concerning the theoretical functioning of the attentional focus effect have arguably been skewed towards hierarchical information processing perspectives, wherein movement plans are purportedly stored in memory and transmitted to the limbs for execution (51). Cognitive, or "information processing" accounts of motor learning, adopt the standpoint that the brain is a metaphoric "computer", processing sensory inputs prior to providing an output in the manner of an appropriate motor response (52). This theoretical perspective relies heavily on schema theory (53, 54), which proposes that the general characteristics of actions (i.e., relative timing and force) are represented cognitively in memory and can be drawn upon for motor execution when required. Different states of memory, or "schemas" have responsibility for different processes, with the recall schema responsible for movement production and the recognition schema responsible for movement evaluation, allowing for error detection and correction. Whilst some features of Schmidt's original (53) motor schema theory have been contradicted empirically in the literature [see (54)], the primary tenet of information processing accounts of motor learning, which still stand today, supports the notion that actions are "pre-programmed", a direct contradiction to mechanisms underpinning ecological dynamics frameworks.

Wulf et al.'s seminal (55) series of studies, which were arguably the impetus for the attentional focus research, first accounted for the benefits of an external focus in a ski-simulator and balance task, with ideomotor-based principles of motor learning [see (56)]. Whilst traditional information processing models present a certain dissociation between perception and action (i.e., input and output), ideomotor principles propose that actions are indeed represented in the brain but in relation to their anticipatory sensory consequences. Prinz's (57) common-coding theory proposes a shared coding system for perception and action. In line with this, Prinz's action-effect principle suggests that "actions are planned and controlled in terms of their effects" (p. 152). Wulf et al. suggested that providing (external) instructions that direct attention towards the effects of one's movements on the environment, only serves to augment the intrinsic association between afferent and efferent information and enhance skill learning. If actions are "coded" in line with their movement effects, then it stands to reason that adopting an internal focus of attention will likely inhibit automaticity of response programming.

Wulf and colleagues (23) tested this hypothesis in a balance task, where participants had to respond to an auditory tone by pressing a button as fast as possible whilst balancing under either internal or external focus conditions. As hypothesised, an external focus of attention facilitated automaticity of the motor system, evidenced by faster probe reaction times combined with enhanced balance performance. These findings led to the conception of what is now well established in the literature as the "constrained action hypothesis". Specifically, Wulf et al. proposed that an internal focus directs conscious attention to otherwise automatic movement processes, that operate more efficiently and effectively if left unattended via an external focus. These mechanisms have since been supported rigorously with various neurophysiological and kinematic measures, including electromyography (EMG), electroencephalography (EEG), and movement variability (58). More specifically, reductions in muscular activity via EMG support the notion of increased movement economy when using an external focus (59) and this effect has now been replicated in dynamic tasks such as jumping (60) or shooting in basketball (61), as well as more static tasks where EMG data is arguably more stable [e.g., within isometric force production; (62)]. Parr et al. (20) extended this by testing EMG together with EEG, during an isometric upper limb force precision task to better understand neuromuscular control as a function of attentional focus. Findings were consistent with previous literature, with the forearm flexor showing greater EMG activity when using an internal focus but also increased EEG alpha activity across the parieto-occipital cortex, a possible indication of increased conscious processing. Support for enhanced cortical processing has also been corroborated with measures of movement planning. Data suggests that an external focus may facilitate offline planning efficiency via reduced pre-movement times in an isometric force production task (63). This is further evidence for increased automaticity and reduced conscious processing. Furthermore, and not surprisingly, these neurophysiological benefits seem to result in more optimal movement kinematics. For example, Lohse et al. (64) showed evidence for increased variability (standard deviation) at the shoulder joint upon extension, when adopting an external focus of attention in a darts throw. This "functional variability" is consistent with Bernstein's (65) degrees of freedom problem, which proposes that movements are only constrained to the point where functionality is optimised.

Wulf and Lewthwaite (24, 25) have since tried to consider these attentional mechanisms in conjunction with psychological factors underpinning motor learning, on the basis that the role of motor, social, cognitive, and affective mechanisms should be considered as complex interactions in line with human function, and not in isolation. Specifically, OPTIMAL theory proposes that adopting an external focus of attention in conjunction with autonomy and enhanced expectancies for success, stimulates advantageous dopamine responses, augmenting "goal-action coupling". This is based on the notion that learners working in these sensorimotor and motivational environments will become more focused on their task goals and direct focus away from the self. Wulf and Lewthwaite speculate that this can result in a continuous cycle of enhanced motor learning, whereby an external focus of attention combined with enhanced expectancies for success results in not only successful movement outcomes, but also increased levels of self-efficacy and positive affect, which in turn influence perceived competence and so the cycle continues. However, early empirical tests of OPTIMAL theory,

provide equivocal support for this framework [e.g., (66–68)]. Simpson and colleagues (67) revealed that although an external focus, led to enhanced motivational states (i.e., self-efficacy, perceived competence, task effort, and positive affect), integrating attentional focus with conditions that enhanced expectancies for success did not provide additional motor-performance benefits over and above an external focus alone, in a standing long-jump task. Further research testing the complex interactions between attentional and psychological mechanisms is warranted.

## The ecological dynamics account of attentional focus

Ecological dynamics is underpinned by the interlinking of dynamical systems theory and ecological dynamics, focusing on the individual-environment relationship mediated through perception-action coupling (69–72). Rather than a linear top-down control of movement, it is the interaction of intention and the information perceived in the environment that controls movement. Consequently, perception and movement are inextricably entwined and cannot be separated. The ecological dynamics approach to motor learning posits that, instead of movement plans being stored in memory and called upon when needed, movement is continuously (re)organised based on the dynamical interaction between organism, task, and environmental constraints.

Individuals' direct perception of the situational opportunities for action (i.e., affordances) in relation to their organismic, environmental, and task constraints, enables them to dynamically self-organise movement coordination into stable states (i.e., attractors), which achieve the desired goal. Consequently, an ecological dynamics framework features greater explanatory power than information processing accounts, with regards to individuals' functional adaptability within a world high in degrees of freedom (72, 73). For example, even in the most exceptional of circumstances when playing soccer (e.g., opposition players obstructing the field of vision, heavy rain, uneven pitch terrain, and temporarily reduced range of movement because of injury), players can still exhibit capacity for successful passes. For both novelty and storage reasons, information processing-based mechanisms are less able to account for such instances than ecological dynamics. Given the explanatory power of ecological dynamics and its growing prominence within motor learning (74), it is timely to develop an "Ecological Dynamics Account of Attentional Focus".

Firstly, the action-effect principle of common coding (57) and the goal-action coupling of OPTIMAL theory (24, 25), account for attentional focus effects by suggesting that movements should be planned in relation to their intended effects/goal for optimal parameter selection; this seminal work predominantly assumes that an external focus most closely aligns with intended effects/goals in all tasks, since actions take place in the external environment (1, 24, 25, 55). However, the presently proposed Ecological Dynamics Account of Attentional Focus (see **Figure 2**) offers a more nuanced explanation for common coding and goal-action coupling effects, based on direct perception. This

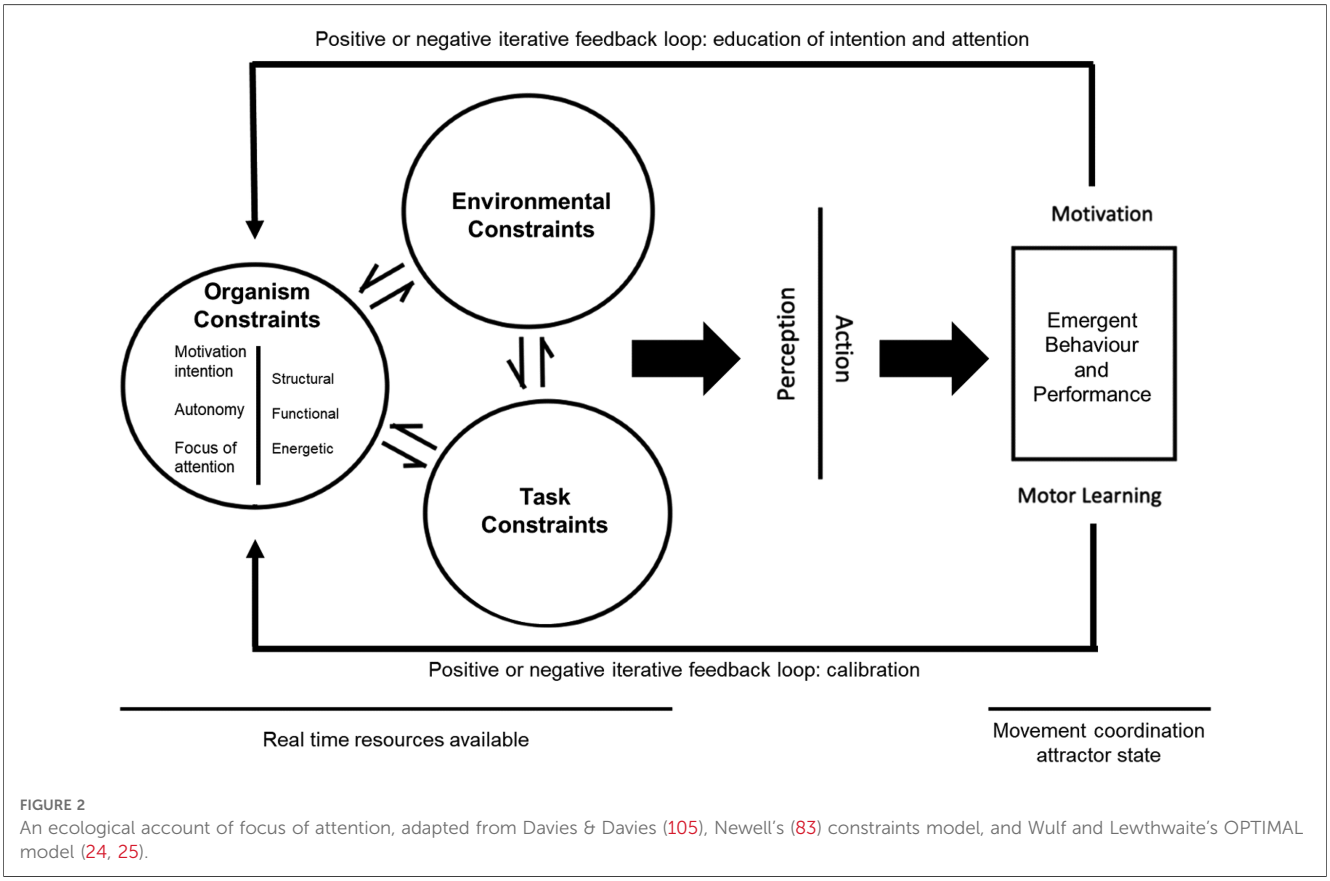


FIGURE 2
An ecological account of focus of attention, adapted from Davies & Davies (105), Newell's (83) constraints model, and Wulf and Lewthwaite's OPTIMAL model (24, 25).

concept proposes that individuals do not perceive the world in terms of absolute physical parameters (e.g., speed and angle of a player) but instead in terms of affordances [e.g., whether the player can be tackled; (75, 76)]. Essentially, the external environment is directly perceived in proportion to the organism's intention and internal bodily motor capacities. Within this framework of perception, cognition plays the role of a supervisor (77, 78) and distributes the organism's limited resources for the perception of information across the body and environment (i.e., specifying information for the constraining of action); thus, adopting a specific focus of attention may be a product of cognition's attempt to distribute limited attentional resources to specifying information deemed most relevant. Similar to previous common coding and goal-action coupling accounts, it can be assumed that within far-aiming tasks [e.g., golf (16)], an external focus of attention on environmental specifying information such as the target, may identify more desirable opportunities for action (affordances) and allows individuals to organise into more accurate and efficient attractor states which hit the target. Relatedly, focus of attention distance (distal vs. proximal) and task relevance (relevant vs. irrelevant) effects may be a product of limited attentional resources being allocated to more vs. less useful specifying information when determining affordances for action. For example, in a far aiming task such as a golf putt, a proximal external (e.g., focus on the club) may provide less valuable specifying information than an external distal (e.g., focus on the ball's trajectory into the target hole), since the latter aligns closer with intention. However, converse to previous common coding and goal-action coupling accounts, within form tasks [e.g., gymnastics: (26)] and proprioceptively guided tasks [e.g., Olympic weightlifting: (37)], an internal focus of attention on bodily specifying information (e.g., arm straightness), may likewise result in the identification of more accurate and efficient attractor states which achieve superior form/technique required by the task. Essentially, tasks guided by environmental specifying information may benefit from an external focus on relevant aspects in the environment, while tasks guided by bodily specifying information may benefit from an internal focus on relevant aspects concerning the body. Therefore, an Ecological Dynamics Account of Attentional Focus features explanatory power across a wider range of foci (i.e., including instances where internal foci yield superior performance) compared to previous common coding and goal-action coupling accounts.|

Secondly, the constrained action hypothesis (23) suggests that an external focus of attention facilitates movement accuracy, physiological efficiency, and cognitive efficiency by directing individuals' attention towards external environmental aspects, which proposedly do not consciously interfere/constrain the motor system's ability to self-organise. However, as identified by Davies (79), the constrained action hypothesis account of external focus effects is already closely aligned with ecological dynamics. The Ecological Dynamics Account of Attentional Focus would predict that directing attention to situationally relevant specifying information would facilitate emergent self-organisation in relation to intention. An internal focus of attention in tasks guided by external environmental specifying information may result in the use of less relevant bodily specifying information for natural self-organisation processes. This may result in reduced accuracy and physiological efficiency via misinformed attractor states, as well as reduced cognitive capacity via inefficient use of attention by needing to evaluate task-essential environmental specifying information while also consciously monitoring less relevant bodily specifying information via an internal focus. Instances of external foci in tasks guided by bodily specifying information may follow a similar pattern. Unlike the constrained action hypothesis, such processes would explain the performance and efficiency benefits when adopting: (a) an external focus of attention in primarily external-information-reliant far aiming tasks [e.g., (61)]; (b) an internal focus of attention in primarily internal information-reliant form or proprioception tasks [e.g., (43)]; and (c) more vs. less task-relevant versions of either focus of attention [e.g., (4, 22, 19)]. For example, in situations where proprioceptive information is paramount for task success, an external focus of attention may direct conscious attention to task-irrelevant environmental constraints; thus, reducing accuracy and efficiency of actions whilst also increasing attentional load.

Lastly, OPTIMAL theory of motor learning posits that adopting an external focus of attention in conjunction with an appropriate motivational climate (i.e., enhanced expectancies and autonomy) augments the "goal-action coupling" (24, 25). Within the Ecological Dynamics Account of Attentional Focus and in line with ecological psychology, the education of intention (e.g., motivation via autonomy and enhanced expectancies), education of attention (e.g., increased sensitivity to specifying information), and the calibration of perception and action sub-systems is assumed to facilitate perception of energy (e.g., wind, object momentum, or ground composition) as lawfully structured specifying-information, which is direct and functionally meaningful to the organism without interpretation (69, 70). Based on this, it is possible to reinterpret the central "goal-action coupling" of OPTIMAL as the use of appropriate specifying information to facilitate perception of detailed and relevant interactions between environmental, organismic, and task constraints (80). Of note is that the organism may indeed have their own motivational (intention) and focus of attention (attentional) constraints, which affect optimal functioning and computation of structured energy as functional specifying information. Motivational constraints may influence the organism's ability to identify affordances (opportunities for action) that align with their goals, sustain task-relevant attention, or inhibit task-irrelevant distractions. Focus of attention constraints may influence whether individuals pick-up or become sensitised to task-relevant specifying information. These constraints interact with environmental (e.g., opposition player location) and task (e.g., environmental external vs. proprioceptive internal) demands to inform perception and guide self-organisation into stable attractor states for action. Through interaction with tasks and the environment, feedback loops in response to action would subsequently lead to adaptations of the organisms' constraints via education and calibration of perception, ultimately influencing action going forward. These changes are more akin to tuning a radio set to be more sensitive to picking up desired frequencies,

than changes in a computer programme made by a programmer. As with more modern and high-tech radios, the changes influence the organism-environment/task relationship (what can be perceived), not what is stored inside the organism. Learning is a gradual process of becoming attentive to, and interested in, what is going on around us. It is a process that requires us to learn to attend to things, rather than acquiring the knowledge that absolves us of the need to do so (81). Consequently, behaviour emerges through the coupling of movement to perceptual information due to the self-organisation of the movement degrees of freedom.

To summarise the aforementioned sections, the Ecological Dynamics Account of Attentional Focus has three core tenets. Firstly, to facilitate optimal perception for action, the direction of the attentional focus needs to be congruent with task demands and their most relevant specifying information. Tasks guided by external environmental specifying information may exhibit superior self-organisation via an external focus on relevant aspects in the environment, while tasks guided by internal bodily specifying information may exhibit superior self-organisation via an internal focus on relevant aspects concerning the body. Secondly, utilisation of foci incongruent with task demands may result in the use of less relevant specifying information for natural self-organisation processes; this may result in reduced accuracy and physiological efficiency via misinformed attractor states, as well as reduced cognitive capacity via inefficient use of attention which needs to evaluate task-essential specifying information while also consciously monitoring less relevant specifying information derived from the adopted focus. Thirdly, it is possible to reinterpret the central "goal-action coupling" of OPTIMAL theory as the identification of appropriate specifying information from the structured energy comprising the world, to facilitate perception of detailed and relevant interactions between environmental, organismic, and task constraints. This reaffirms the impetus to select an attentional focus (organism constraint) in relation to environment and task constraints. Overall, the Ecological Dynamics Account of Attentional Focus assumes that attentional focus is not one size fits all, but dependent on its suitability when combined with the interacting constraints which influence perception for action; even intra-individually as performers continuously attune to perceptual information that specifies action. This links to the ecological mantra for coaching, helping the individual to define "where to look, not what to see" (82).

Crucially, the Ecological Dynamics Account of Attentional Focus provides a novel and arguably more congruous explanation for focus of attention effects than common coding, constrained action hypothesis, and OPTIMAL theory (23–25, 55). As noted by Davids (79), the mechanistic explanations put forward by Wulf and colleagues, somewhat borrow from both information processing and ecological dynamics (i.e., constrained action hypothesis' championing of self-organisation), while also constraining themselves via assumptions of an external focus of attention's superiority in all conditions. An ecological dynamics standpoint provides a more conceptually consistent framework, as well as a more flexible account in instances where an internal focus of attention may prove desirable. This latter aspect may be in part because, from an ecological dynamics perspective, the distinction between an internal and external focus of attention is less clear-cut. An external focus of attention and its resultant benefits have long been conceptualized as focus on "movement effects" (55). However, an affordance is a relationship between an organism (internal aspects) and the environment (external aspects). From an ecological dynamics perspective, it may be beneficial to reconceptualise the beneficial effects of focusing on "movement effects" as representing focus on task-relevant aspects of performance or specifying information, rather than exclusively external information *per se*, as suggested by Herrebroden (21).

## Practical recommendations

When designing effective practice environments in relation to attentional focus, we would advise the following process is adhered to: "function before context" i.e., first consider the primary objective of the practitioner (e.g., skill learning, technical refinement, fostering movements that minimise injury risk, or developing techniques that are under robust pressure) and then consider the context in relation to the motor skill (e.g., far aiming vs. proprioceptive tasks), the relevance and proximity of possible foci (where appropriate) and the appropriateness of instructions altogether (see **Table 1**).

Whilst these practice decisions may well be underpinned by competing theoretical approaches, an applied solution can still be found. For example, the benefits of a proximal attentional focus for novices can be underpinned by theoretical components of constrained action hypothesis (23) as well as Newell's (83) stages of skill acquisition (i.e., assembling a coordination pattern; gaining control and adaption of coordination; and skilled optimisation of coordination). In assembling coordination patterns, an individual is likely to need and use more proximal information. In the gaining control, during the stabilization phase, learning is focussed on attunement to specifying perceptual information, which can then be exploited in the skilled optimisation phase through effective calibration of action to the perceived information.

The principles of a constraints-led approach can be used to guide practice design that supports an education of focus of attention toward task-relevant information. These principles being: (a) goal orientated practice with clear session intentions; (b) manipulation of constraints to afford exploration of opportunities for action; (c) representative learning design that includes perceptual information that will be available in performance; and (d) repetition without repetition, encouraging the development of adaptable and effective movement solutions.

## Future research directions

Although the fundamental principle of adopting an internal or external focus of attention is simple, there remain ample avenues for future research. Above all else, the presently proposed ecological dynamics-based mechanisms for focus of attention effects are conjecture. However, so are information processing-based explanations until it is understood whether underlying neurophysiological mechanisms resemble information processing

TABLE 1 Practical solutions to support applied practice.

| Applied challenge/context | Applied practice solution | Practical example | Theoretical rationale | Supporting evidence |
|---|---|---|---|---|
| *When there is a decision to be made to select the most appropriate external focus in a skill requiring coordination of several body parts* | Proximal external focus when working with individuals in early stages of learning and distal external focus when working with individuals in late stages of learning | A novice focusing on the racquet motion during a tennis serve versus an expert focusing on the intended ball trajectory | Focusing proximally allows novices to attend to skill-relevant information and assemble optimal coordination patterns. Focusing distally promotes motor automaticity for experts. In the gaining control, during the stabilization phase, learning is focussed on attunement to specifying perceptual information which can then be exploited in the skilled optimisation phase through effective calibration of action to the perceived information | (16, 17, 84) |
| *When there is a need to "simulate" an external focus because this doesn't exist naturally* | Using visual images to replace body parts Using a replacement for the missing information | Imaging a 'platform' in place of the forearms during a volleyball pass Using pegs to represent the position of fielders when practising in a cricket net | Prevents individuals focusing on body-centred information and constraining actions Gives a purpose to external focus when the practice is devoid of the information that would be present in a competition | (29, 30, 85) |
| *When a meaningful external focus cannot be easily identified* | Adopting a holistic focus of attention | Focusing on making your movement 'feel explosive' in a standing long jump task | Prevents individuals focusing on body-centred information and constraining actions | (28, 86–88) |
| *To identify clear session intentions* | Goal-orientated practice | Having outcome goals rather than movement form goals | Frames interactions with task and environment. Supports the development of picking up information and using strategies that may vary depending on individual differences and the functionality of information and movement coupling | (89) |
| *When the demands of competition must be matched to practice* | Representative learning design Ensuring that task-relevant information is available in practice | Designing tennis practice to contain more information that is representative of competitions such as the behaviour and intentions of opponents | Supports attunement to the information that will be present and specifying in competition | (90–92) |
| *When there is a need to enhance the extent to which skills are adaptable to changing environments* | Promoting self-organisation | Using constraints manipulation to destabilise current attractor states without using declarative instructions for body awareness | Developing dexterity or adaptiveness to constantly changing external information. Reducing the chances of choking under pressure through reinvestment of conscious control | (93) |
| *To ensure coupling to specifying (task-relevant) perceptual information* | Variability of practice | Using varied practice to ensure that information that is present in an environment but not reliable or specifying (such as distance for ball hitting), is not tightly attuned to, but instead through learning, more reliable information in the form of 'time to contact' is used instead | To support the attunement to specifying, rather than incidental, information during practice by ensuing that only specifying information is available in all practice environments | (94) |
| *Affording exploration of movements and perceptual landscapes* | Manipulating constraints to the task, environment, and organism | Using occlusion goggles to educate attention to more effective information sources such as more distal target related information such as the movement of other players. Encouraging a focus on outcome and finding multiple solutions | Constraints can be manipulated to change the available information sources—focusing education of attention to more specifying information. Setting up movement problems and asking learners to find a solution, then find a different one | (95, 96) |
| *To prevent injury caused by long-term technical errors within a movement* | Five-A model of technical refinement Using task constraints that highlight the movement form used | Using a process of analysis and bodily awareness to correct adverse elbow abduction in the weightlifting snatch movement Using a connection ball under the arm of baseball pitchers to highlight forearm flyout and give transitional feedback about changes to more effective movement solutions | Supports error detection and correction via a process of analysis, awareness, adjustment, (re)automation, and assurance Disrupts current movement solution and provides transitional feedback about the changes in movement solutions | (40–42, 97) |
| *When refining motor skills by altering biomechanics of movements that are already well established* | Facilitative somaesthetic awareness | Using internal focus verbal cues to "run with a flat foot" during gait retraining in running | Supports error correction and enables individuals to 'relearn' movements | (43, 46, 38) |
| *When developing broader psychological interventions to enhance self-efficacy or positive affect* | Using an external focus of attention combined with enhanced expectancies for success based on OPTIMAL theory of motor learning | Placing a cone to represent normative standing long jump data for individuals in the bottom 5th percentile in a standing long jump and directing individuals to try to jump as far past the cone as they can | Addresses the complex interaction between motivational and attentional factors that facilitate skill learning via goal-action coupling | (24, 25, 67) |





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or ecological dynamics (98, 99). Out of the rather limited number of studies that have investigated the cortical processes underlying attentional foci, results suggest that internal foci of lesser task relevance may: (a) prevent visual inflow of environmental information to shield internal body-focused processing, via reductions in posterior alpha power (20, 100); (b) induce volitional control of attention to adjust behaviour responses to feedback via decreased frontal midline theta (101, 20); and (c) unbind muscles from a synergistic control strategy via reduced beta corticomuscular coherence between the contralateral motor cortex and effectors (20). Importantly, these neural mechanisms align with the proposals of ecological dynamics; the selective shielding/prioritisation of environmental vs. organismic constraints, cognition's supervision of attention to benefit perception for action, and binding/unbinding of synergistic control strategies, supporting the notion of an organism's self-organisation in response to its environment and task. Future research should continue to elucidate the neural mechanisms underlying both focus of attention and ecological dynamics, to inform theoretical understanding.

Another benefit of an ecological dynamics standpoint is its ability to account for results that are ill explained by common coding (57), constrained action hypothesis (23), or OPTIMAL theory (24, 25). Seminal literature's staunch advocacy of an external focus of attention (1) has resulted in comparatively little evaluation of instances where an external focus of attention may not be superior. However, noteworthy exceptions include appraisals of internal foci for somaesthetic awareness (38), a holistic focus of attention in instances without a clear external movement effect (28), and developmental benefits of adopting an internal focus of attention in proprioceptive sports [Olympic Weightlifting: (37)]. Overall, a body of literature is beginning to emerge which aligns with the concepts of ecological dynamics in suggesting that foci other than an external focus of attention can be facilitative. Future research should make concerted efforts to further understand applied and theoretical nuances within focus of attention.

With regards to applied nuances, the ecological dynamics-based framework has demonstrated itself popular within talent development research for its pertinent emphasis of multivariable effects [e.g., (102)]. It is proposed that no single independent factor can account for real-world differences in performance; instead, it is the combination of task (e.g., practice history), organism (e.g., anthropometrics and technical/tactical awareness), and environmental (e.g., relative age and sociocultural) constraints (73). Consequently, ecological dynamics offers a useful framework through which to investigate focus of attention effects observed in highly applied (i.e., ecologically valid) settings. For example, when comparing external vs. internal focus effects in a complex five-part gymnastics floor routine, assessed via the Federation Internationale de Gymnastique Code of Points, Lawrence et al. (26), observed no significant difference in performance based on attentional focus. In the absence of a more nuanced theoretical framework, null findings in the ecological study of Lawrence et al. were subsequently argued to be a product of methodological limitations (1, 27). However, it is possible that nuanced interactions between a multitude of variables meant that an internal focus of attention was able to yield unique benefits for participants. Going forward, ecological dynamics provides a promising framework for investigations in ecologically valid settings to avoid interpretational/publication bias.

Lastly, given doubts raised by recent research concerning an external focus' ubiquitous superiority over an internal focus [e.g., (37, 38, 43)], it may be timely to re-evaluate what constitutes an optimal focus of attention, depending on skill and individual differences. To-date, investigations concerning possible foci of attention have been "top down" in their exploration of available foci; researchers traditionally identifying and prescribing the focus adopted by participants. Comparatively little research has attempted to utilise a "bottom up" approach [e.g., (36)], wherein optimal/preferred foci are identified by participants themselves. Such approaches may help identify further nuances to the focus of attention effect, in addition to distance (14), task relevance (19, 22), and breadth (50). Promising avenues to address this omission in current literature include think aloud protocols (103) and virtual reality (104). These methods respectively allow researchers to better assess and manipulate contextual information to ascertain novel nuances within the attentional foci adopted by participants.

## Conclusion

Literature surrounding focus of attention has come a long way since the original conception of internal and external labels by Wulf et al. (5). This initially binary choice has now expanded to encompass distance (14), relevance [e.g., (4)], salience [e.g., (26)], ecological validity [e.g., (37)], somaesthetic awareness [e.g., (38)], and wider psychological motivational factor considerations (24, 25). However, despite these advances in understanding attentional focus, theoretical explanations still rigidly advocate external foci [see (23, 24, 55)]. This is in stark contrast to the growing body of evidence demonstrating that external and internal foci of attention have distinct advantages depending on situational constraints. Accordingly, the presently proposed Ecological Dynamics Account of Attentional Focus is one of the first to provide a sufficiently flexible theoretical framework, which can explain instances of internal "and" external focus superiority. The implications of this are plentiful in facilitating more varied consideration of which focus may be optimal for a given scenario; research into both theoretical and applied aspects of the focus of attention phenomenon may just be getting started.

## Author contributions

All authors contributed equally. All authors contributed to the article and approved the submitted version.

## 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.

## Publisher's note



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# (Re)conceptualizing movement behavior in sport as a problem-solving activity

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The use of the term *problem-solving* in relation to movement behavior is an often-broached topic within kinesiology. Here we present a clear rationale for the concept of problem-solving, specifically pertaining to the skilled organization of movement behaviors in sport performance, and the respective processes that underpin it, conceptualized within an *ecological dynamics* framework. The movement behavior that emerges in sport can be viewed as a problem-solving activity for the athlete, where *integrated movement solutions* are underpinned by intertwined processes of perception, cognition, and action. This *movement problem-solving process* becomes functionally aligned with sport performance challenges through a tight coupling to relevant information sources in the environment, which specify affordances offered to the athlete. This ecological perspective can shape our lens on how movements are coordinated and controlled in the context of sport, influencing practical approaches utilized towards facilitating dexterity of athletes. These ideas imply how coaches could set *alive movement problems* for athletes to solve within practice environments, where they would be required to continuously (re)organize movement system degrees of freedom in relation to dynamic and emergent opportunities, across diverse, complex problems. Through these experiences, athletes could become attuned, intentional, and adaptable, capable of (re)organizing a behavioral fit to performance problems in context—essentially allowing them *to become one with* the movement problem.

KEYWORDS

movement behavior, problem-solving, ecological dynamics, dexterity, perception-action coupling, affordances (ecological psychology)

## Introduction

With only seconds left to play in the championship game and her team currently behind by a single point, a basketball point guard advances the ball down the court, dribbling while she weaves seamlessly through the traffic of others. She continuously remains ready to pass the ball in a moment's notice as she scans the landscape for an open teammate, who may be afforded a scoring opportunity. A heavyweight boxer stands just a few feet from an opponent who has sincerely bad intentions. He moves in and out of "the pocket", attempting to stay in range just long enough to detect an opening based on his opponent's behaviors, throw a number of punches in combination, and quickly back out of this danger zone to a distance where there is less risk. A running back takes a handoff from the quarterback, and within fractions of a second, he is met in the gap by an aggressively pursuing linebacker who is just a couple of yards from him. This culminates in the need for the back to appropriately perceive the situation, make a rapid but accurate decision, and carry

out a movement strategy where he escapes from the tackle attempt of the defender. After solving the first problem, the back will need to immediately solve another emerging problem in the performance landscape.

It is clear that complex movement problems exist everywhere within sport at all levels, and they continuously present both challenges and opportunities, of varying relative intensities, to athletes of all demographics. As Verkhoshansky and Siff (1) stated, "sport then becomes a problem-solving activity in which movements are used to produce the necessary solutions." Skillful athletes are not always bigger, faster, and stronger than their peers, but they are often those able to coordinate their movement responses in solving a wider variety of problems, often within challenging and unpredictable contexts, while performing under the constraints of immense pressure, fatigue, and other potential perturbations.

The use of the term *problem-solving* in relation to movement behavior is an often-broached topic within kinesiology. However, a clear definition of this concept of problem-solving, especially as it pertains to skilled movement behavior in sport, and the respective processes which may underpin it, is worth articulating within an ecological dynamics framework. Thus, the purpose of this conceptual analysis is to adopt an ecological perspective in evaluating theory and evidence as to how athletes may solve movement problems in sport. Viewing movement behavior (i.e., the coordination, control and regulation of actions) in sport as a problem-solving activity can also bring important practical implications. An ecological conceptualization emphasizes the contexts of performance and could influence the nature of practice activities and designs used by practitioners, with the goal of facilitating dexterity (2) within athletes. While the primary target audience of this conceptual analysis is coaching practitioners and skill acquisition specialists working within sports, we hope that the ideas help shape how others (e.g., those in research) conceptualize and study movement behavior in sports.

Various conceptual propositions have been advanced to describe how athletes may coordinate, control, and organize movements under the challenging demands of competitive sporting environments (3–5). Traditional models, derived from cognitive and experimental psychology, have been adopted, primarily taking an organism-centered perspective by emphasizing psychological and neural processes, such as memories, knowledge acquisition, and the processing of information indirectly through representations stored within the brain (3, 6). However, our conceptual analysis highlights an *ecological dynamics* framework to problem-solving within sport, steeped in a systems orientation, addressing the ongoing relations between oneself and the environment (3). Utilizing an ecological perspective, we will aim to unpack how the movement behavior that emerges in sport could be viewed as a problem-solving activity for the athlete, where the integrated processes of perception, cognition, and action underpin the movement solutions coupled to performance problems through relevant information sources in the environment. This distinction could offer readers a greater perspective to more comprehensively narrate the movement problem-solving story within sport, by respecting the individual (with unique "effectivities" or characteristics), the performance context (i.e., the problem), and the content (i.e., the specific movement solution to emerge).

## Problem-solving in the context of sport

According to the Merriam-Webster Dictionary, the definition of *problem-solving* is simply, "the process or act of finding a solution to a problem." Other resources may mention the idea of complexity and/or difficulty as it pertains to specific challenges to be addressed in solving a problem. Across many contexts, the use of the term problem-solving, or contemplation around the emergence of a solution, often conjures up an image of a mostly mental construct or a process that is neuro-cognitively driven (3, 7, 8). However, when investigating the (re)organization of *movement solutions* in skill adaptation (8), especially in the challenging athletic contexts of sport performance, the problem-solving process and the movement outcome as a solution, may differ from other domains. We reject problem-solving as proposed by (captured within) traditional computational theories (e.g., information-processing; 9, 10), as these assume an *organismic asymmetry* (11), suggesting that individuals only have "indirect" access to the information in the world that needs processing (interpretation), and movement actions come to be due to stored representations within the brain (8, 12).

In this paper, we discuss ecological ideas on learning to solve movement problems when interacting with a dynamic performance environment, which is contextually dependent on a rich mix of actions, perceptions, cognitions, and knowledge of the environment, drawing on the insights of Gibson (13), Bernstein (2), Newell (14), Kugler and Turvey (15). When a theoretician, researcher, or coaching practitioner utilizing an ecological dynamics framework, is referring to problem-solving as it pertains to the context of an athlete moving skillfully within sport, they are not referring simply to content knowledge about the environment as the sole basis of information underpinning their perceptions, cognitions and actions (16). So, what exactly are they attempting to explain?

The goal of the problem-solving process in sport is oriented around the organization of a solution that adequately addresses the most pertinent issue(s) confronting the athlete (i.e., the problem solver) at that point in time. The emergence of the most effective solution will be largely dependent on the contextual situation since the athlete is typically engaged in some form of motion when interacting with the dynamics of the competitive environment. The interactive *problem-solution dynamics*, demanding changing states of organization to adapt to contexts of sport competition environments, differ significantly from that which is typically studied, understood, or explained across behavioral contexts where long-term memory or information processing dominates. Instead of just relying on knowledge about the environment stored in long-term memory, athletes are required to interact with information that is continually emerging, changing, and unpredictable, relevant to organically

resolving an *alive movement problem* (17), which will differ (subtly or significantly) each time it is faced. At a certain level, no two problems in sport are ever truly the same; thus, no two solutions will be the same either. Similarly, two significantly different solutions could emerge to solve the issues or challenges present under the constraints of what appear to be similar problems (4).

The movement problem-solving process in sport often takes place under considerably different constraints than problems presented in other domains. An athlete rarely has the luxury of identifying, or deliberating on, a list of alternative options to employ in trying to solve a problem. There simply is not the time, nor the need, to thoroughly analyze the problem to find out its causes in the way one might in other settings. Many sports have problems that change from moment to moment, presenting a variety of opportunities to solve them in authentic, yet functional, ways (18, 19). Navigating movement problems in this inherently complex and often challenging environment requires athletes to detect and use highly specifying information to make decisions and organize functional movement solutions (20, 21). Gibson (13) spent a long time conceptualizing the nature of the information used to regulate interactions with the environment, where he argued that deeply relevant information resided in the structure of the surrounding environment. Namely, the structure of the surrounding energy arrays may provide information that specifies *affordances* (13)—how an individual can interact with surfaces, objects, other people, and events, for example, especially when in motion. The concept of affordances (which we will expand on later) describes the action-relevant properties of the environment: the opportunities or possibilities for action within the solving of a movement problem (13). Affordances point both ways, referring to both the environment and the animal in a way that no other term really does—linking the athlete and the environment, as well as the problems and the solutions (13), making them inseparable in both our studies and explanations.

An ecological approach emphasizes the value of *knowledge of* the surrounding structures of the environment in interactions more than the content *knowledge about* the environment (8, 13, 22). Our conceptual analysis maintains distinctions between a coach's over-reliance on knowledge about the performance environment which defines instructions, descriptions and feedback to instruct athletes during learning, prominent in traditional pedagogical methods. An emphasis *on* knowledge of the performance environment underpins actual behavioral interactions (involving perception, cognition, and action), from an ecological perspective. We draw attention to the importance of designing learning environments to enhance athlete-environment interactions (rather than instructing players what to think, perceive and do—the traditional behaviorist perspective). Through using knowledge of the performance environment, athletes can learn to utilize affordances available in manipulated task constraints and through coupling their perception and action, framed through intentionality. This conceptualization has been advocated in ecological dynamics and was recently summarized in the work of Woods and Davids (23) which highlighted potentialities of coaches facilitating athlete learning through "making/doing and not telling".

## Skill according to an ecological dynamics framework

Based on these insights, from an ecological dynamics perspective, Araújo and Davids (8) reconceptualized *skill acquisition* as "the emergence of an adaptive, functional relationship between an organism and its environment." Skillful movement behaviors, therefore, when viewed through an ecological lens, could be conceived of as the emergence (with practice and experience) of coordinated movement solutions by an athlete, which are essentially dynamical products of continuous performer-environment interactions. This ecological view moves skill acquisition away from acquiring content knowledge about the environment towards skill in adapting to the dynamics of the environment (and its problems) and begins to position the expression of skill closely to that of effective problem-solving through one's movement.

Though many associate the work of Nikolai Bernstein with ideas of coordination in movement systems (i.e., *Bernstein's degrees of freedom problem*), it is clear Bernstein felt that a more appropriate scale of analysis for movement should extend beyond the motor system, looking deeper into relations and interactions between systems—connecting movement problems with the solutions coordinated to solve them. According to Bernstein (24), "dexterity is the ability to find a motor solution for any external situation, that is, to adequately solve any emerging motor problem." He added, "dexterity is not confined within the movements or actions themselves but is revealed in how these movements behave in their interaction with the environment, with its unexpectedness and surprises". The key to skill adaptation is the emergence of movement solutions, softly assembled (15) to functionally fit the unique and unfolding problem.

The aforementioned work (2, 13, 22, 24) helps shape the systems narrative around the tight coupling between perception and action and the athlete and their environment (i.e., signifying the fit between problem and solution). Viewed in this way, animals and the surrounding environment are inseparable and incapable of existing without one another (13), as they have a mutual and reciprocal relationship with each other; this idea underlines the relations between athletes and their movement problem-solving processes within competitive performance. Athletes cannot organize a solution without first being presented with a problem. This notion implies that scientists should not analyze or attempt to understand movement solutions in isolation without paying equal respect to the contextual problem the behavior is organized to satisfy.

If the essence of movement behavior in sport is in the problem-solving activities which are dynamically and continuously emerging from the athlete-environment relationship, then the questions arise: How does an athlete coordinate the proper relations of their movement system with the

environment? Furthermore, what individual subsystems, and associated processes, may underpin this movement problem-solving process?

## The integrated movement problem-solving process

To understand the phenomenon of emergent movement behavior in sport, Seifert et al. (19) acknowledged that: (a) it occurs at the ecological scale of analysis (i.e., studied through the ongoing, reciprocal relations between the athlete and the environment); (b) perception and action are viewed as emerging from these interactions; and (c) it is predicated on the circular causality of the relationship. Under an ecological framework, the movement behaviors in sport, reconceptualized as problem-solving activities carried out by the movement system of the athlete, are subserved by the coordination of perception and action with respect to information in the world.

### Intertwined nature of perception, cognition, and action

The above contention captures the importance of individuals—in our case, athletes—being both *perceivers* and *behavers*, where perception and action processes can be thought of as tightly coupled because perception is required to adequately regulate behavioral actions and acting allows for the pick-up of additional information about the problems in the world, which will further serve to guide subsequent actions in a tightly coupled fashion (13, 25). Within this, the concept of *behavioral dynamics* (26), which integrates an information-based approach to perception with a dynamical systems approach to the organization of action (27), may enable further understanding as to how detected information in person-environment relations channels the movements which emerge in the pursuit of goal-directed actions. At a certain level, the problem of the organization of behavior is synonymous with perception and action processes feeding into one another as movement becomes coupled to information (27).

The current state of affairs between the unfolding problem-solution dynamics can be assessed through perception of information (see **Figure 1**) which is a dynamic process involving the entire human movement system of the athlete (16, 28). With increased exposure to practice and performance, athletes may become more sensitive to (i.e., *perceptually attuned to*) which informational variables to attend to and when to attend to them. Practice and experience should *educate their attention* to these variables, allowing athletes to more functionally regulate their movement actions across various situations (8, 29). Through this process of attunement, the athlete can create constant, purposeful contact with a complex, ever-changing environment, through the perception of information and a range of decisions that they actively undertake, regulating their interactions to solve emergent problems.

It should also be acknowledged that emerging movement solutions in sport are always goal-directed. Meaning, movement solutions are organized for the functional purpose of achieving a specific outcome in the competitive performance environment. Therefore, performance behaviors need to be interpreted with reference to that functional purpose (26, 30). Accounts of movement behavior in sport must capture the nature of the athlete's intended goal(s), seeking to characterize how movement solutions are coordinated in relation to the problems and challenges of the environment. This could point to a further understanding of how cognitive processes may be situated in the emergence of movement behavior (6, 31). Though there have been questions raised over a lack of explanation about how cognition may function in ecological theories (3, 5), perception could be considered a fundamental type of cognition (13). Additionally, cognition may also be considered the coordination of intended interactions with the performance environment (32). Finally, Reed (33) called cognition "a set of capacities by which observers gain knowledge of their environment". Cognition, provided by perception, could support an athlete's knowledge of the environment, allowing them to be aware of events, objects, and others that exist (attention), have existed (memories), may come to exist (anticipation), and ought to exist (planning, prediction). According to Reed (33), actions, perception, and cognition are "knowledge-yielding processes". Perception is a cognitive function of the most essential kind because it yields knowledge of affordances available in a performance environment.

Therefore, an athlete's cognitions may scaffold the information they perceive while also influencing how they ultimately coordinate their actions (20, 34). In an ecological approach, cognition is proposed to operate in an embodied and embedded fashion (6). Here, cognitive processes combine with other subsystems to form a comprehensive, integrated system, supporting the use of knowledge of a performance environment. This unfolds potentially through a *resonance mechanism* in the central nervous system where an athlete becomes tuned to available information (28). For example, if a basketball player perceptually picks up a teammate entering the paint near the basket, the ball handler needs to be "tuned in" to the available information in the performance environment for an affordance (e.g., a passing lane opening up to throw the ball to a moving teammate who is separating from a defending opponent) that invites a quick pass from behind the three-point line. Following Gibson's ideas, when the teammate is detected near the opponent's basket, the point guard's perceptual system resonates with that information for an affordance (13, 28). Further, this has the potential to give rise to a mover displaying *skilled intentionality* by being open and responsive within a rich landscape of opportunities (30, 35), where the affordance landscape will then channel the specific way the ball handler acts (e.g., when, where, and how to coordinate motor system degrees of freedom to complete an accurate and timely pass to the teammate).

Though we may be able to neatly define each of the various processes (see **Figure 1**), because of their tightly intertwined nature, perception, cognition, and action would not be viewed as separate processes, functioning in isolation, under an ecological dynamics framework. Instead, perception, cognition, and action could be considered inextricably linked as the constituent,

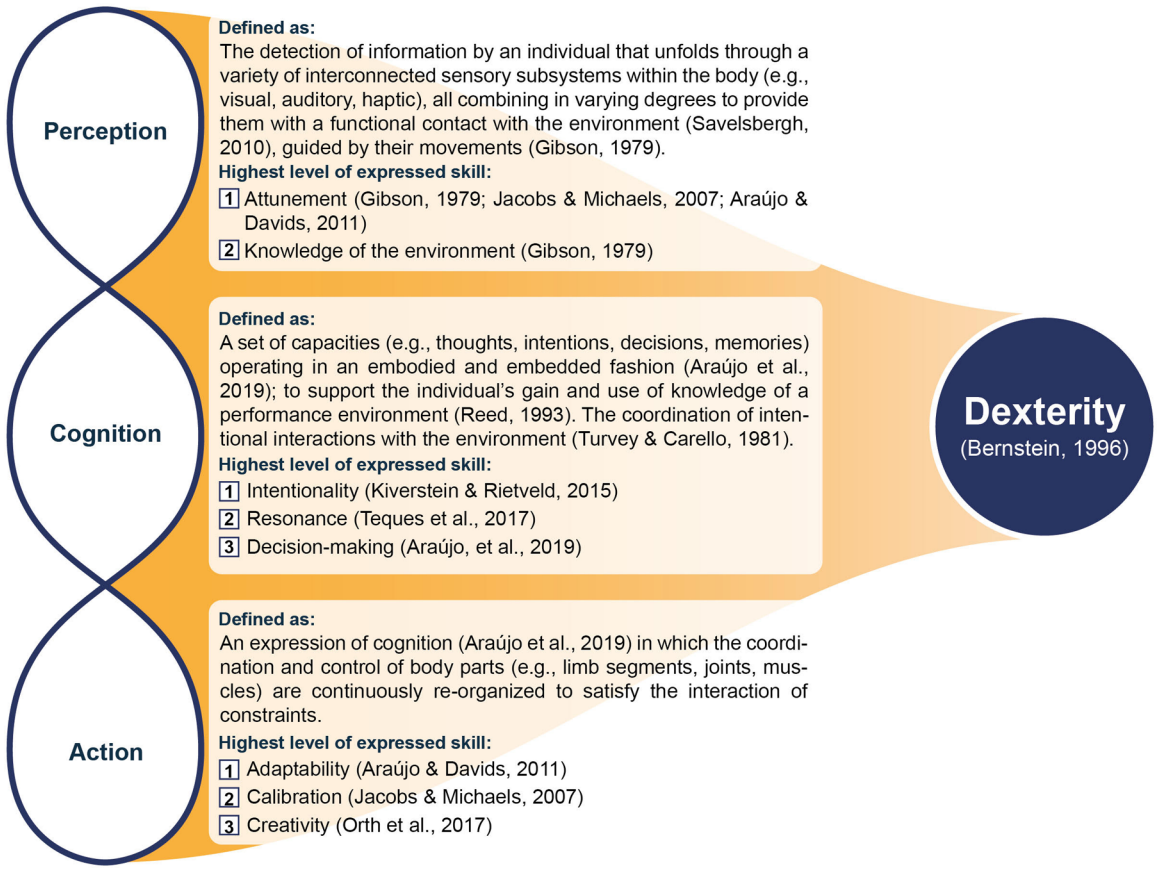


FIGURE 1
Processes of the human movement system. Defining the interwoven processes of the human movement system and their interdependent contributions to carrying out movement behaviors in sport within an ecological dynamics framework, on the path towards the expression of dexterity.

interacting elements of one *integrated movement solution* (IMS)—in slightly differing, yet highly related, accounts of a holistic, *movement problem-solving process* (MPSP).

## Continuous (re)organization of system degrees of freedom

Context requires an individual to adapt to changing external demands (i.e., constraints where a movement emerges) and internal states (i.e., within the individual). Newell (14) proposed that *coordination* could be defined as the function constraining the free variables of the human movement system (i.e., degrees of freedom) into a behavioral unit—capturing how the component parts and processes of a system come into relation with one another. What an athlete is attempting to coordinate is not just a motor response, but a *functional behavioral unit*, organized to fit the dynamical needs of their world. We propose that the IMS is a functional behavioral unit that harnesses degrees of freedom within and between the dimensional levels across the system (of perception, cognition, and action) and points us to how those processes may be integrated to underpin this MPSP (see **Figure 2**).

Ultimately, this problem-solver paradigm extends Bernstein's degrees of freedom problem beyond the motor system, looking deeper into the relations and interactions between subsystems and processes. Just as there are numerous ways that the degenerate motor system can be coordinated and controlled (e.g., joint positions, timing and sequencing of patterns), there will be degrees of freedom perceptually and cognitively as well. For example, perception can unfold through a variety of interconnected sensory subsystems within the body (e.g., visual, auditory, haptic), all combining to varying degrees to provide the athlete with functional contact with the world (36), as they attempt to detect the most relevant information regarding opportunities present for authentically solving a peculiar problem. Closely connected to perception, the athlete's cognitive degrees of freedom can also be coordinated in various ways, led by their constantly changing intentional aims, the diverse thoughts they may have, their unfolding movement strategies, and the wide range of decisions that they can make as a mover interacting with the dynamic problems within the world.

Processes of perception, cognition, and action are interdependent with one another, interacting with circular causality, underpinning movement systems as complex, dynamical systems (20). Through these interconnections, dynamics in the organization of the

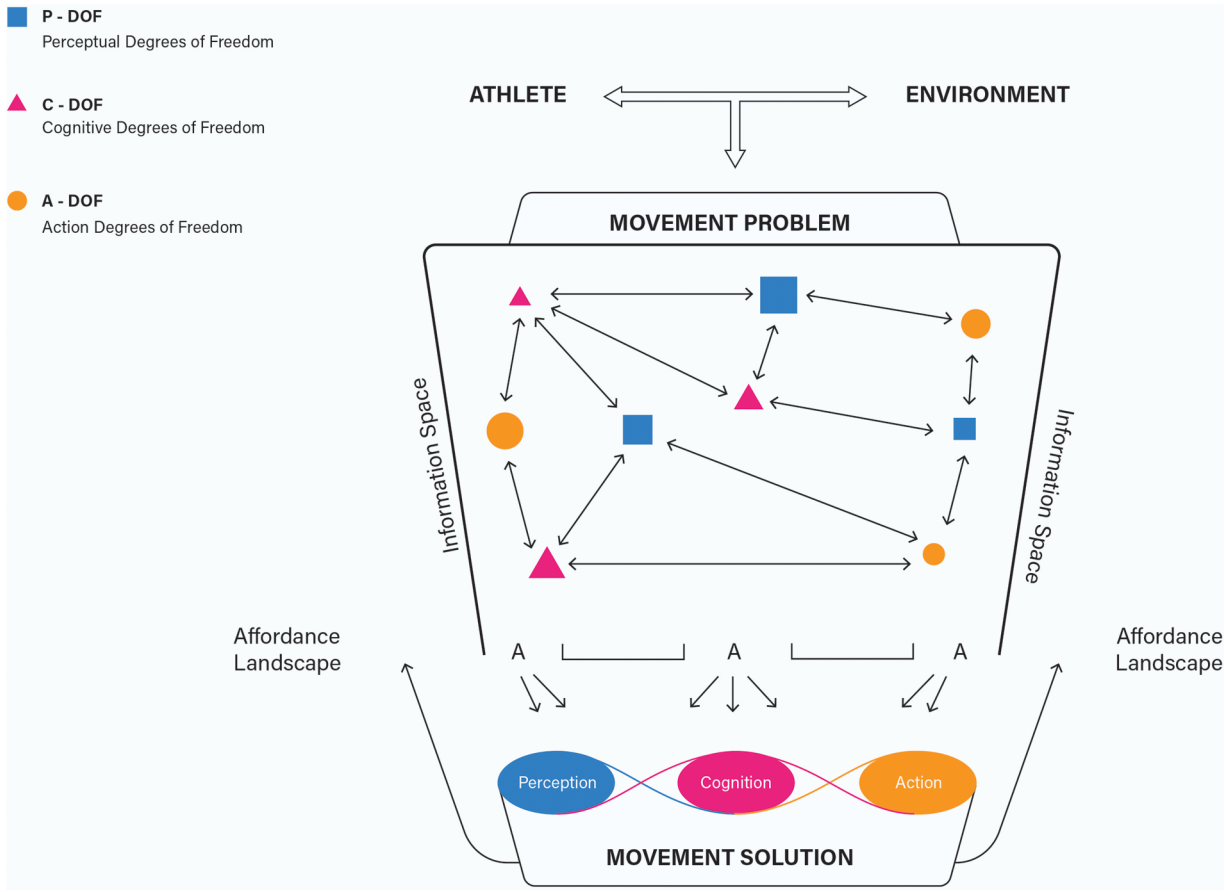


FIGURE 2
The integrated movement problem-solving process. The integrated nature of the processes of perception, cognition, and action underpinning the Movement Problem-Solving Process (MPSP) as an athlete coordinates system degrees of freedom in relation to specifying information and affordances present in solving a movement problem.

self-regulation process at a local level (such as the specifying information a player is picking up, how and when the athlete is picking up the information, etc.), could perpetually feed into the dynamics of other processes (e.g., intentions underpinning performance, movement strategy employed, how actions are being regulated), as well as global, system-wide movement behavior. Skill adaptation is enhanced because constituent parts and related processes of a human movement system can fit together and operate in many different ways or configurations (i.e., displaying system *degeneracy*; 37).

The IMS, or the MPSP, can be investigated at and across multiple timescales of analysis, ranging from the local interactions of movement performance (i.e., brief moments in time or numerous sequences unfolding successively in a singular play) to more global patterns of evolved movement behavior indicative of skill acquisition and learning over significant periods (i.e., days, weeks, months, or years). In sports, movement problem-solving may not be adequately captured through the expression of a discrete event, isolated entity, or simplified response, as it is occasionally reduced to within traditional motor control or learning research (e.g., button-pressing, stimuli-response aiming tasks). Within the typical performance constraints of most sports, we may not always be able to accurately determine where one movement solution, or even one movement problem, ends and another one begins for the athlete. Due to context-conditioned coupling variability (38), one movement problem does not typically exist in isolation because it is integrated with other deeply interrelated, interconnected challenges and problems. Thus, the MPSP could be best conceptualized as a constantly unfolding process where the system's degrees of freedom are continuously (re)organized, and circular causality is displayed throughout the relations between system components (see **Figure 2**, which shows arrows pointing both ways between the degrees of freedom of each of the human movement system's dimensional levels to depict the potential relationships emerging during movement behavior organization). To illustrate, imagine a soccer player dribbling a ball, concurrently scanning the landscape of the performance environment for opportunities to pass to a teammate, execute a shot on goal, or continue to move throughout space, navigating around defenders and teammates in an evasive manner. Moment-by-moment, various local movement problems, challenges, and decisions will continue to emerge and unfold dynamically, which the player must attempt to deal with in their

own unique and authentic fashion. These problem-solution dynamics could be studied as such on any number of micro or macro levels.

Recent research (see 4, 17, 20, 21, 39) has extended our understanding of these theoretical constructs in ecological dynamics, elaborating how these ideas can be practically utilized in skill enhancement programs. In particular, there has been a rhetoric threaded throughout this work on the need for athletes to seek functional movement solutions and adaptive behaviors. For example, when presenting their idea of *wayfinding*, Woods et al. (39) highlighted how movers purposefully and skillfully regulate through their environment underpinned by this deeply entangled relationship of perception, cognition, and action; encompassing real-time, actively engaged problem-solving.

## The concept of affordances

As outlined, to sufficiently understand movement behavior in sports, one should investigate the problem-solution dynamics at hand, and the reciprocal nature of their changing states of co-organization. To assist us in comprehensively doing so, it could be helpful to utilize the concept of affordances. Acknowledging affordances as an emerging relationship between an individual and the environment (13, 40) and therefore creating a link between the two, as well as the problems and the solutions, has clear implications that become relevant to problem-solving in sports. Because it is the information within the world which specifies the affordances offered to an athlete, affordances bring a needed practical perspective on the role and use of information in the solving of movement problems (16).

### Affordances as functional semantics

Affordances have been positioned as a conceptual pillar for the study of movement behavior within sports (41). In particular, Fajen et al. present the key features of affordances that allow them to be especially helpful in investigations. They highlighted how affordances (a) are real; (b) are animal-specific; (c) capture the reciprocity and coupling of perception-action; (d) allow for prospective control; (e) are meaningful; and (f) are dynamic. Due to their ability to provide the athlete with information about their ongoing relationship with the world, informing individuals how they could move to achieve their behavioral goals (i.e., solving problems in the performance environment), affordances could be viewed as *functional semantics* for sports (41).

Affordances go beyond being just mere possibilities or opportunities for acting in a certain way within a performance environment as they could also be viewed as invitations or solicitations (34); it is almost as if the environment is calling for a specific way of acting, connecting the performer-environment through the constant exchange of information. At any moment, there will be a variety of simultaneous and successive affordances which are available for detection, each inviting or soliciting a player to act, though they will differ in degree of attraction for various reasons. Thus, the athlete will still need to decide which affordance to select and act upon after perceiving them out of a rich landscape of inviting opportunities. Ultimately, agency is needed in accepting affordances as the athlete will still be the source of their own activity and the vehicle of the emerging movement behavior.

In recent work by Araújo and colleagues (6), more elaborate hypotheses were offered to depict how cognitive processes, particularly those related to decision-making, may exist as constituent elements of the IMS that emerge as one perceives, selects, and acts upon the affordances in the world. In their work (see 31, 42), decision-making is closely linked to problem-solving. Because *the world is its best model* and behavior is always dependent on circumstances, both cognition and decisions will also be emergent processes, like perception and action (6, 20). Generally speaking, perception is of affordances, and actions, which are an expression of cognition, are the realization of the selected affordances (6).

### Information and affordances within sport contexts

As noted earlier, the potential affordances connecting the athlete-environment system are specified by information provided by surrounding energy arrays, residing in the structure of the sporting environment. Thus, the movement solutions that emerge will depend on an athlete's sensitive detection of and close coupling to these relevant information sources. Though additional research is certainly needed, some research has begun to explore the nature, role, and use of information in the regulation of movement within some sport contexts (e.g., 16, 41), such as team sports like rugby codes (42–44) or basketball (45), as well as various combat sports (46, 47).

Taking this research into account, it would seem that information pertaining to interpersonal distance (46, 47), particularly within dyadic relationships (e.g., between opponents or teammates), could be an informational variable specifying affordances, channeling the movement problem-solving processes of athletes. As Gibson (13) stated, "Behavior affords behavior," meaning it is how two (or more) individuals interact in the competitive performance environment that gives rise to the possibilities for athlete performance behaviors to emerge. Though the informational variable of interpersonal distance may be transferable across some sports, its critical values (i.e., how this information will be utilized in the regulation of movement) will be sport-, context-, and individual-specific. Additionally, it is likely that information about interpersonal distance alone may not be enough to explain the movement behavior that emerges in context (43). In other words, athletes may also be attuning to other informational variables to specify the affordances present when faced with solving complex movement problems. These variables could relate to relative angles or velocity values between competitors (42, 44), variations in gaps between opponents and teammates (17, 20), postural characteristics of opponents (17, 45), or any combination of these variables (17, 20, 44).

# Discussion

Researchers and practitioners alike may begin to adopt ideas related to the themes presented within this conceptual analysis, ultimately shifting their paradigm to one oriented around movement behavior as a problem-solving activity. When one's scope of analysis and perspective changes in this way, embracing an ecological dynamics framework and problem-solver paradigm, it can lead to tremendous changes in the ways they approach their craft, what they attempt to study in their investigations, and how they may set-up their environments in order to capture (i.e., scientists) or facilitate (i.e., coaches) the emergence of skill.

## Implications for research

In contemplating where the fields of movement, learning, and pedagogy could advance to better understand how movement solutions emerge in different performance contexts of sport, it is worth highlighting some additional areas for future research to consider. First, there is an apparent paucity of research that studies sport movement skills *in situ*. Though it is obviously a daunting and possibly intrusive task to adequately unpack movement behavior in this fashion (i.e., in competitive performance contexts), we must recognize the need and importance of this endeavor. In studying movement behavior: context is everything! The problems which confront athletes, as well as the coordination of IMS which emerge, will be highly specific to the performance context which they inhabit (48).

Second, it has been well over a decade since Fajen and colleagues proclaimed the potential for the use of affordances in studying the problem-solution dynamics in sports (41). Yet, there is still limited research that has attempted to fully explain the presence of affordances across a variety of sporting contexts, while addressing their explanatory role in how they may influence the emergence of movement behavior. There is a need for research that can further unpack the MPSP in terms of the intertwined processes of perception, cognition, and action in relation to the opportunities detected, selected, and acted upon out of the rich landscape of affordances (6).

The adoption of this problem-solver paradigm (underpinned by ecological dynamics) is useful for enhancing our understanding of the problem-solution dynamics in sports that are beyond invasion-based team games (e.g., soccer, rugby codes, basketball, American football) or dyadic relationships in combat sports, as we explored earlier. Alive movement problems are everywhere and within all sporting environments, and they require athletes to organize an adaptable IMS. Researchers should continue to investigate the potential informational variables that performers are detecting, and how they are organizing their movement behaviors in relation to the affordances they perceive, both within and across diverse sporting contexts. Some research has been conducted in this area (see 49–53 for examples), but it needs expansion to further impact practice.

Additionally, many of the investigations into information, affordances, and movement behavior in sport have been conducted with athletes who perform at relatively low levels of skill. To understand the problem-solving processes of athletes across the timescales of learning, we should study how those who display dexterity (i.e., the ability to solve any emerging movement problem) interact with the varied and complex problems of their world, through their use of specifying information, differently from their less skilled counterparts. There is a need to understand more about the behavioral organization of the MPSP of highly skilled, elite athletes and how the degrees of freedom across the dimensional levels of their movement systems (i.e., perception, cognition, and action) are coordinated.

## Practice design for the facilitation of dexterity

Supported by ideas underpinned by theory and empirical evidence, coaches and support practitioners can design practice environments to facilitate enhanced movement problem-solving for the athletes they partner with in training. Information sources that athletes become attuned to, as well as their common ways of behaving, are influenced by the situations and conditions that they routinely face in practice environments. Thus, coaches should aim to set alive movement problems (17) to present to the athlete in practice and training. These types of problems are those where the strategies and outcomes are unpredictable (e.g., the inclusion of moving opposition and teammates in team sports situations, a resisting opponent in combat sports). Here, athletes will be required to perceive a vast array of informational sources specifying a rich landscape of affordances to potentially interact with, actively make decisions around, and coordinate functional actions, often in more variable fashions, in relation to (6, 20). As affordances emerge and decay dynamically within these alive movement problems, it could allow for the search, discovery, and exploitation of a wider range of authentic IMS to positively transfer into perceiving and accepting affordances in the competitive sports arena (20). Yet, many training or practice settings often contain highly sterile and predictable tasks which expect an athlete to simply repeat an idealized motor response with little emergent problem-solving or decision-making needed (i.e., the equivalent of *less alive* movement problems consisting of *dead* technical patterns). To assist coaching practitioners in designing *more alive* movement problems, it may be useful to ask a number of pertinent questions regarding the inclusion of key conceptual principles within activities being presented to athletes in any practice environment (see **Table 1**).

Research questions may still exist on: (i) how to ensure representativeness of practice designs (i.e., for the movement problems presented); (ii) how to appropriately set a movement problem that adequately stretches a specific athlete's movement behavioral dynamics to a place of continued evolution; (iii) how to determine if a movement solution is 'correct'; and (iv) how to effectively guide a performer's perception, cognition, and action

TABLE 1 Alive movement problem setting checklist.

| Does the movement problem presented to the athlete in practice: |
|---|
| 1. Keep the problem-solution relationship intact? |
| 2. Present a task disposition representative of the competitive performance environment? |
| 3. Contain relevant sources of information for the athlete to regulate their movements? |
| 4. Keep perceptions, cognitions, and actions deeply intertwined? |
| 5. Maintain a practical and relevant goal as an intention to channel the movement solution? |
| 6. Allow for the continuous (re)organization of system degrees of freedom? |
| 7. Require the athlete to authentically connect to the problem in their own unique way? |
| 8. Maintain a certain level of unpredictability, requiring the athlete to actively make decisions as needed? |
| 9. Present emerging and decaying affordances? |
| 10. Change in some meaningful way each time it is faced (i.e., repetition *without* repetion)? |
| The more questions you answer "yes" to, the more likely it is that an *integrated movement solution* will emerge that is functionally fit for the peculiar movement problem, guiding the athlete *to become one with* the movement problem. |
| If you answered "no" to any of the above questions, how can you adjust the movement problem by manipulating relevant constraints to make it more *alive*? |

Pertinent questions for coaching practitioners to ask when designing alive movement problems in practice for the athlete's pursuit of organizing functionally fit movement solutions transferable to competition.

processes to become functionally fit to match the problems in their world. However, one thing is clear: dexterity in sport does not equate to repeating a particular movement pattern more consistently or employing a given strategy more automatically (2). Instead, dexterity centers on the athlete being able to solve any emerging movement problem (20, 21, 24), across situations (e.g., facing opponents with different capabilities or styles of movement skill, operating under various spatial and temporal demands), and conditions (e.g., in various weather conditions, facing pressure, under levels of fatigue), allowing them *to become one with* a dynamic, complex problem through interactive information transactions.

For highly interactive problem-solving to occur, the complexion and disposition of most movement problems in practice should vary frequently from repetition to repetition. This type of learning opportunity could allow athletes to gain experience in functionally self-regulating the processes involved with their movement problem-solving—thus aligning with Bernstein's (2) original thoughts on *repetition without repetition* —with the goal of the mover becoming skillfully attuned, intentional, and adaptable. Woods and colleagues (39) describe this process of learning in practice, emphasizing that coaches should "challenge the learner to experiment through performing, adapting and creating movement solutions that best answer his/her individual needs within a given context." Ultimately, by navigating through the solving of a diverse range of alive problems, athletes will learn how to coordinate their perception, cognition, and action by continuously (re)organizing the degrees of freedom of the human movement system and adjusting the relations between these integrated processes to fit together in various ways. Through this exploration and search process, athletes strengthen their connection to the unique problems of the environment, tightly coupling their movement in close relation to the affordances offered within those problems.

When athletes solve movement problems in this highly emergent fashion, practitioners can expect the expression of a number of signature movement properties[1] (e.g., variability, abundance, creativity, authenticity), sometimes viewed as undesirable in more traditional approaches. In an ecological dynamics framework, these respective movement properties are not to be frowned upon or avoided; instead, they should actually be pursued as they are recognized as key performance indicators of skillful and dexterous movers (19). Recognizing that all athletes have their own individual constraints and movement histories, practitioners may be well served to avoid imposing their own idealized ways of perceiving, deciding, and acting upon the athlete (54). Instead, skill optimization may stem from attunement, abundance, authenticity, and adaptability. Being that no two problems in sport are ever truly the same, and sporting environments can present a diverse range of problems to athletes, it would stand to reason that the athlete having a plethora of potential movement strategies and options that can be flexibly adjusted to meet the needs of a peculiar problem becomes a worthy aspiration for coaches to pursue. Thus, learning environments should also reflect this goal.

To assist in the emergence of highly functional and authentic movement solutions, coaching practitioners, acting as learning environment designers, should aim to guide and facilitate, employing communication methods (i.e., instructions and feedback) that strive to educate the attention (pursuing perceptual attunement) and intentions of the athlete (29). The goal of this type of *direct learning* approach would be to encourage the perceptual search for relevant information sources and the affordances they specify, while allowing the athlete to explore the breadth of their entire movement toolbox. As the athlete gains experience and exposure, they will become more attuned to specifying information sources, being intentional about the goals to be achieved in particular situations, and being adaptable in how their movement is calibrated and coupled to the relevant information within the problems of the sport environment.

## Author contributions

SM was responsible for the overall reconceptualization outlining this conceptual analysis, while all authors (SM, TY, and KD) contributed equally to the writing and editing of the manuscript. All authors contributed to the article and approved the submitted version.

[1]A detailed discussion of this related literature is beyond the scope of this conceptual analysis. Interested readers should refer to the works of 18, 19, 20, and 21.

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## Conflict of interest

Authors SM and TY are employed by Emergence, LLC. The remaining author declares 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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# The experience of laser light feedback in back-squat resistance training

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**Introduction:** The purpose of this paper is to contribute to the existing literature on performance in resistance training (RT) by addressing how a phenomenological perspective on experiences with inter kinaesthetic affectivity can illuminate experience of practicing RT with non-verbal, visual feedback provided through laser lights attached to the barbell.
**Method:** The material is created from qualitative interviews and using inter-kinaesthetic affectivity as analytical lenses.
**Results:** The findings show how participants interpret the feedback in the moment and explain how they adjust their movement in dialogue with the feedback and enable the "uptake" of feedback in their embodied experience. The findings show how the participants developed an awareness of how they can equalize the balance on their feet.
**Discussion:** We discuss what this means for the understanding of the training process in terms of how practitioners can use the uptake of non-verbal, visual feedback to immediately adjust the quality of their performance by responding kinaesthetically and bodily. The discussion contributes to the question of what kind of role a practitioner's own kinaesthetic and bodily experiences have in the development and organization of RT. Perspectives that include the lived and intersubjective body as a knowledge position are promising for illuminating the whole bodied engagement that is necessary to understand how to perform RT.

KEYWORDS

visual feedback, phenomenology, embodiment, inter-kinaesthetic, automated, strength, technology, intracorporeal

## Introduction

Performance in resistance-training (RT) is usually examined by using quantified measurements, and the research interest usually lies in the effects of the RT. To teach and improve the execution of RT exercises, trainers, instructors, or teachers often provide verbal feedback on how the training individual can correct their movements (1). It has been shown that the presence of an instructor can assist in both learning (e.g., provide instructions) and motivation during RT. Personal communication of feedback is strengthened by the instructor's skills in relaying the information, as well as by their experience and ability to individualize the feedback. Importantly, the specific feedback of a trainer is influenced by their experiences and expectations, possibly leading to projecting these preconceptions onto the trainees. Since experiences and expectations are socially constructed, this gives rise to different interpretations between the trainer and the trainee, that can challenge the subjective experiences of both parts in such a relationship (1). A rather novel approach to feedback is the use of non-verbal,

technological instructions which can present valuable and use cases and objective feedback in different movements.

Researchers have examined the feasibility of using non-verbal feedback and instructions in correcting bodily movements such as laser lights in RT (2), tactile information in snowboarding (3), and auditive feedback in golf swing (4). These studies concluded that non-verbal feedback (i.e., tactile instructions, sounds, or lights) was potentially useful for correcting and instructing movements. Importantly, these studies were cross-sectional and, therefore, do not inform us about the potential longitudinal effects these feedback methods may have on the efficacy of the training or on the trainers' and participants' own experiences. Moreover, the feedback method was not compared to traditional, verbal instructions. Still, these studies present novel and interesting ideas for future research into how able participants may be to understand and utilize the non-verbal feedback if the instructor becomes more absent and provides fewer verbal instructions.

Examining the feasibility of using body-lights to inform RT-movements (2) and tactile instructions to correct snowboard technique (3), the authors briefly outline how the participants were instructed on using the feedback and indicates that the participants could utilize the information provided by the feedback independently after only a brief introduction. Interestingly, Spelmezan (3) also interviewed the participants after completing the trials to elucidate their perspective and how they generated meaning of the feedback. The authors concluded that (1) the non-verbal feedback was experienced as useful for the participants, but (2) that non-verbal instructions should not be applied during the first sessions when introducing new movements. Instead, they proposed that the first sessions should include verbal instructions only, followed by a gradually increasing focus on the non-verbal, automated feedback. A period of an instructor introducing the non-verbal feedback method is likely needed for people to be able to independently understand and utilize it (3). This relation between the instructor's use of feedback and the participant's interpretation of it is sparsely described in previous research and warrants further examination. In a recent publication (5), our research group conducted, to our best knowledge, the first intervention study comparing verbal and non-verbal feedback (i.e., visual via laser lights) in developing experience in the back-squat exercise. We followed a similar procedure to what Spelmezan (3) proposed. However, we introduced both methods (i.e., non-verbal and verbal) from the start and gradually decreased the instructor's feedback, thereby allowing the participants to independently use and interpret the non-verbal feedback from the lasers attached to the barbell. The findings indicated that, despite indicative measurements of lifting technique remaining unchanged, the participants increased their maximal strength and self-selected training resistance without an impairment of the technical execution. By interviewing the participants that received non-verbal feedback via the laser lights, we can further examine how it was understood, experienced, and utilized by individuals with no prior experience with either the exercise or the feedback method.

In this article, we will use the concept of inter-kinaesthetic affectivity which we suggest that the phenomena examined in the previous studies can be linked to (2–4). This concept describes how informative and influential the feedback is and how readily the individual understands and allows the stimulus to affect their movement (6). However, it calls upon a further examination since little is known about how inter-kinaesthetic affectivity plays a role in the training individual's uptake and utilization of non-verbal, visual feedback compared to verbal instructions. In the current context, one can imagine that verbal instructions and the understanding of these cues are influenced by individual experiences and interpretations of words and phrases. Hence, it is possible that verbal instructions in RT can be interpreted in a different way than what the instructor intended and that some meaning is changed in the interpretation process between the instructor and the instruction-receiver. To mediate the information-processing during the uptake of data from stimulus, it has been suggested that humans tend to off-load a portion of the cognitive work onto the environment and collect information on a need-to-know basis to be replaced with kinaesthetic awareness (7).

Non-verbal feedback in the context of RT can originate from the trainee vi lights attached to the person or the equipment (2, 5). This approach may create a form of inter-affective relationship between the trainee and the perceived stimuli from the non-verbal feedback where they interact with- and move each other in a circular relationship (8). The expression of movement instantly prompts a related impression that is tailored and synchronized to the individual person and their movement pattern. To date, the existing literature provides limited knowledge about the personal experience of interpreting feedback while conducting RT, and current research has relied mainly on quantitative methods. Consequently, there is limited insight regarding the experiences people have in receiving and interpreting feedback. However, there is a growing interest for the lived experiences and personal interpretations of feedback (9). Therefore, we are interested in whether this potential inter-affectivity introduces a bodily knowledge that is readily available for the training individual. Moreover, we ask the question whether such knowledge can be understood and taken up effectively since the environment is moved in a perfect interrelation with the individual expression of movement. Since the personal experience of those who undertake RT is of importance for whether they continue the RT in the long run (10), it is desirable to understand how people interpret and experience feedback when they participate in RT. We designed an interview study exploring (I) how young, women without RT experience interpret the non-verbal feedback during RT and (II) how the women's interpretations of non-verbal, visual feedback may allow for new insights about the approaches available for RT instruction. Our questions aim to explore the structure of the bodily awareness that should be elucidated to understand how progress and satisfaction in the practice occur.

# Materials and methods

## Design

We designed a qualitative interview project to address the research questions and used semi-structured interviews to explore

the informants' lived experiences of receiving non-verbal feedback from the laser lights during RT. The interviews were guided by a phenomenological paradigm, informed by perspectives on movement experience from Fuchs and Koch (8), Sheets-Johnstone (11), Behnke (6, 12), and Zahavi (13). We used the research literature on embodiment and lived experience as a backdrop to apply an approach to qualitative research that allowed us to engage proactively and exploratively with the informants. We also took inspiration from Zahavi (13) who argues that "qualitative researchers should rather strive to let their own research be informed by central phenomenological concepts such as lifeworld, intentionality, empathy, horizon, historicity, and the lived body". Zahavi (13) inspired us to be aware that conducting phenomenologically informed qualitative research is not merely a question of being open-minded and interested in first-person experiences. It is also very much about adopting and employing a comprehensive theoretical framework concerning the subject's relation to themselves, to the world, and to others (13).

In a phenomenological approach it is central that researchers are open and aware of the phenomena in the study. This indicates that to investigate experiences of performance in RT, it is necessary to take into consideration that the training experiences might be difficult to articulate, and therefore give time and space for "letting the informants be" and trust their own words (14) Indeed, most bodily habits and the perception of one's own body might go unnoticed by the consciousness in daily life and even in training practises. Hence, we designed the project while being aware that getting a substantial material would rest on our way of integrating openness and creating the potential to describe and analyse the phenomenon of RT in a novel way (15). It means to search for substantial descriptions from the informants' meaning generation in their own words (16). To allow us to reach a deep insight into the experiences of the participants, we sought to learn about their interactions with- and understanding of the feedback and generate meaningful knowledge by analysing their experiences using concepts such as inter-kinaesthetic affectivity and intersubjectivity.

## Selection and recruitment

A purposive sampling technique was used to recruit informants who could illuminate the research question (17). Five females with no prior systematic RT experience in the last eighteen months were recruited from larger group of ten participants who were taking part in a quantitative study examining the feasibility of using visual, non-verbal feedback in developing the back-squat technique (5). The study compared the changes in strength and technical execution of the back squat following five weeks (10 training sessions) of training while receiving either verbal or visual feedback. Throughout the intervention, each session included three sets of ten repetitions with a self-selected external load that corresponded to approximately two repetitions in reserve and an eight out of ten rating of perceived exertion (0 indicating no exertion at all and 10 being maximal exertion). The verbal feedback was standardized by only using a selection of four ques that were developed in cooperation with a group of highly experienced personal trainers. The visual feedback group received information about their spatial positioning (i.e., frontal, sagittal, and transverse planes) from laser lights projected on a reflective whiteboard with lines indicating how the lights should travel during each lift. Briefly described, the laser lights were attached to the barbell and moved in concert with the participants' movements, making minor deviations from a straight line immediately visible. The participants were novices in the exercise, but displayed acceptable technique when the external load was within a self-selected, manageable range. Hence, the role of the feedback was to correct the technique rather than introducing the participants to the exercise. During the first two training sessions, the instructor was present and assisted the participants in generating an understanding of how to interpret the laser lights' feedback. In the last eight sessions, the instructor only provided motivational support and was available for discussion and reflection about the training. The informants gave their written informed consent as well as verbal assent before the interviews began. We reminded them before the interviews about their right to withdraw from the study at any time without any negative consequences, and about how their anonymity would be maintained (18). Furthermore, we made sure to clarify our roles in the interview context as researchers and highlighted the fact that we were interested in hearing about the informants' lived experiences since they were the insider experts in this context (19). The research procedures were processed by the Norwegian Centre for Research Data (reference 440571) and ethical approval was granted by the university's local ethics committee (reference 21/08477-3).

## Material creation

We conducted a total of five semi-structured research interviews in October 2021. Interviews took place immediately after the participants had completed their fifth out of ten prescribed training sessions. The last author (GHE) conducted three interviews and the first author (NS) conducted two interviews due to logistical reasons. Importantly, both authors were present in the first interviews to ensure that the setting was as similar as possible on the final three interviews. However, the authors also remained mindful of the importance of allowing the natural intersubjectivity that arose between the researcher and the informant in the specific times and places to take place, and not compromise the flow of the dialogues by attempting to make the interviews more similar. Each interview started with the researcher verbally repeating information about the project, the research question, expected duration of the interview, as well as how we would maintain the participants' anonymity. The semi-structured interview guide comprised the two following open-ended questions: (1) "Could you tell us about your experiences from the training with the non-verbal feedback?" and (2) "How would you describe your own change or improvement in the exercise following the training?". As already stated, we used a phenomenological and reflective approach to the interviews, which opened the opportunity to ask

follow-up questions about the themes that the informants themselves chose to bring up in their answers (20). This happened when they talked about the meanings of how the body responded to the laser light. We became aware of a way of verbalizing experience and discovered that asking follow-up questions gave insight into the informants' way of expressing their experiences (21). As Rapley (22) clearly express, interviews are also highly dependent on- and emerge from the specific local interactional context which is produced in and through the conversation. By recognising and asking follow-up questions we obtained substantial descriptions, which we consider the argument for choosing interviews (20). It means that interview is not only about asking, but as already mentioned, to be remain aware that the phenomenological approach seeks to uncover the intersubjectively accessible structures that may be shared between interlocutors (23). Hence, the accounts of the training were co-produced in the encounter between the researchers and the informants. In addition, Depraz et al. (24) explicitly accounts for the role of the researcher's sensitivity and are concerned with the researcher's responsibility for creating space for verbalization of experiences, to make available what is not spontaneously expressed. Each interview lasted between 15 and 30 min. The interviews were recorded and transcribed verbatim using Microsoft Word (Microsoft, Redmond, WA).

Work on the analyses started informally immediately after the interviews. We were particularly aware of how the different participants accounted for their version of the training experience and that the material was produced in a local context in the actual training space (25). The voices of the informants and the dialogical approach to the interviews were the most important guidelines and we identified those parts of the informants' expressions that could shed light on the research questions (26, 27). The material from the interviews provided an opportunity to explore the lived experiences of the informants that they were able to articulate. We began by reading the transcripts and listening to the tapes to get a sense of the whole material, which is a general recommendation in qualitative research (28). After getting a sense of the whole material we used the method's whole-part-whole procedure to further work with the material and started to re-tell what the informants had told us (16). Our strategy for the further analyses was to listen to the recordings and read the transcripts to grasp the meanings of how the participants expressed how they created meaning from training and interacting with the laser lights' feedback. By suspending our reading of the material through the concept of bodily inter-affectivity, we started to discover how these phenomena functioned as underlying premises for how the process seemed to be progressing according to the participants. We first identified some of the experiences that the women had in common, albeit expressed using slightly different phrasing. Next, we used their expression to identify themes and experiences that we could re-formulate and thereby elucidate the most (16). By staying close to the expressions that appeared in the material and avoid "intrusive and overly imposing interpretations", we used the informants' own words and expressions. With the support of the chosen perspective, we were able to elaborate on the experiences. Rather than using a rigid and predefined process of identifying the themes that occurred most frequently in the material, we allowed ourselves time to get as familiar as possible with the transcribed interviews to get a clear sense of what was perceived as important and meaningful by the informants. Moreover, our experiences from the interviews (e.g., body language and when the informants appeared enthusiastic) also helped us in identifying and creating themes that resonated with the lived experiences of the informants. Our discoveries in the material helped us use and activate the theoretical framework and we conducted a circular process of familiarizing ourselves with the material and exploring relevant concepts and literature throughout the work with re-formulating the information from the interviews (29). Finally, we continued with some phenomena where the phenomenological framework was used to create the headlines that we discovered in the interviews.

## Results

The following section will present the primary recurring themes that emerged from the interviews.

### "I did not know how I moved"

The informants seem to have realized during the training that they lacked an innate awareness of how their bodies moved. In other words, they explain how they were previously unable to feel the positioning and movement of their body parts, and phenomenologically speaking, they were in the "natural attitude", like one who stated that "… before, I didn't know that I loaded the left foot so much, I had no idea that I did that" and continued to explain how she became "very surprised that I could be so little aware of it". Another informant, when asked if she could feel postural changes in the body during the training, told us "No, usually not" and elaborated that she only might have felt any postural change after continuing with poor lifting technique for a while. Several statements from the informants indicated that albeit challenging to *feel* their body position, receiving the information from the laser light has helped them recognize some bodily feelings and become able to connect the feelings to specific positions or movements. In general, the informants expressed a realization that indicates that when they started to perceive the feedback within their own bodily receptivity, the back-squat training gave them new meaningful information. They told us that they became aware of their bodily movement patterns that they reflected on not being aware of by training without feedback or using a mirror. These experiences became deepened in the theme which we will present in the next section.

### "It was difficult in the beginning—until I learned to interpret the laser light"

The second theme that emerged from the interview material illuminate the participants' descriptions of how they felt like they

needed to learn how to utilize the non-verbal feedback before their bodies fully grasped the meaningful communication with the laser light. One of the informants explained how it was difficult to "see what was right and wrong" based on the feedback. She then went on to tell us how she needed the instructions from the research leader in the first phase of the training to learn what the different indicators from the laser lights meant in relation to the movement. When she learnt how she could interpret the feedback, and that she could then go on to practice more independently from the research leader's guidance. The same reflections arise from other interviews, with one who explained that "it is difficult to learn [the back squat technique] based on the laser if you don't have knowledge about the laser". The same informant said that "there must be both for me to learn something", referencing the non-verbal feedback and the exercise itself. In other words, the early phase of the training where the research leader was present and introduced them to both the feedback and to the exercise appears important and meaningful for the informants. These and other statements from the informants also highlight the fact that there are two elements that need to be learned: (1) how to perform a back squat and (2) how to use the non-verbal feedback in a meaningful way in their execution of the exercise.

## The laser light and the body in inter-affective communication

The informants have also learnt how to create balance on their feet and based on the feedback. Many of the informants described the uptake of the feedback as an automatic process where the laser light communicates directly with the body. One expressed her experience in the following way: "it's not the foot that controls the light, but it's the light that controls the foot". The same informant went on to describe a process that had occurred where she had become able to control the laser light by immediately correcting her movement if the feedback informed her that she was off balance. Another explained that she "… can see much more clearly when the technique becomes poor". The informants appear to have learnt the laser's way of informing them about their movements and become able to respond to its feedback rapidly and in a way that results in a correction of the errors and deviations in the movements. Once the participants learned how the laser functions, they began an even deeper communication between the body and laser as an inter-affective circle. Of note, one informant told us that "… the heavier the load becomes, the easier it is to feel which foot I place the most weight on," and continued by explaining that "… the laser makes more sense the heavier the load becomes". Later, she described that her focus was increased along with the loading.

## The laser light vs. other forms of feedback

As noted above, the informants described an increased understanding of the non-verbal feedback and ability to respond to it in a rapid and appropriate way. Some of the informants further compared their new experience with the laser lights' feedback to their previous experiences with receiving verbal feedback from a trainer or instructor. One stated that "it's much easier to read the lights" compared to adhering to verbal instructions. She explained that verbal feedback can be abstract and difficult to transform from listening to the voices to altering their own movements. Verbal feedback can be misunderstood and may not always correspond to how she experienced the movement. Another informant compared the laser feedback to using a mirror and said that "The laser is helpful compared to using a mirror, where you only see it when you're doing it *very* wrong!". She explained that the laser feedback provided a clearer and more evident picture of her specific movements compared to seeing her whole body in a mirror. The experiences indicate that it is difficult to understand the meaning of kinaesthetic responses in the body. Moreover, it appears that visual information in a mirror or verbal instructions do not provide immediate practical use for correcting one's own movement. Based on how the informants told us about their experiences, the non-verbal nature of the laser feedback appears to have been experienced as useful in a sense that only meaningful and relatable information needed to be harvested from it and that it was understood directly and immediately in the body.

## Perceived safety via the feedback and the research leader

All five informants spoke about and were aware that the research leader played a role in their RT progression. Knowledge and understanding are shaped in a liminal space and the participants need "the other" to understand the laser (the researcher with his knowledge and guidance). They all highlighted that it is important how the researcher spoke to them and that the training took place in a welcoming atmosphere, which they point to as a precondition for their experience with improving their technique. They pointed to a new acquisition of knowledge concerning the "right way to do a back squat". When they felt the new embodied understanding, they expressed "ownership" and were able to put this knowledge into use, and as one stated: "If I'm ever going to have to do squats, I've learned how to do them a little more correctly". Both the researcher and the laser light together represented safety for one of the women who expressed that "Yes, I think it has been a form of safety to have the lights saying […] something about how my technique is". Referencing a previous encounter with the back-squat exercise, she explained that "when I was practicing back-squat and was about to add more weight, I was thinking "ok, now I'm adding weight and I know that my technique becomes worse", but with the lights you sort of get a clearer answer to whether, well, if you're doing it right". She added "… probably a combination of that (the lights), and that you (directly to the researcher) are there and provides some additional comments. And that I can ask you (directly to the researcher)". The informant described that in order to benefit from the actual training session, she needed to be familiar with the context, and she underlined that the knowledge of the researcher played an important part.

### Learning with the light—learning without the light

The last major theme that was identified comprised the informants' reflections about how they thought training the back squat without the non-verbal feedback would be for them. One of the women said that "I'm excited to see how it is without the lights when this is over. If the body has actually taken [the feedback] in and can work without it. Or if it's the lights that control it (the movement)". The same informant went on to recount a session during the intervention where she tried not looking at the lights for one set in order to "feel a little bit" how performing the lifts would be without the feedback. She explained how her experimentation with looking and not looking and the laser lights made her somewhat unstable, and she recalled the research leader's instruction on the specific execution. When asked about how she thought she would experience training without the laser feedback in the future, she told us that "… I think that I would miss it, yes—to actually get an answer from the lights". These statements raise questions about the position the women give the non-verbal feedback in facilitating improvement in the exercise, as well as the kinaesthetic awareness in RT that women may have acquired or if they may feel overly dependent on the constant feedback of the laser.

## Discussion

In this study we sought to explore the experience of laser light feedback in RT. Feedback is information communicated to the training subject that is intended to modify his or her thinking and/or movements to facilitate development or improve execution. The discussion is centred around the primary themes that were identified in the interview material. It has been suggested that feedback has no intrinsic value (9). Rather, it is the use and uptake of it that count when learning. In the following section, we discuss the findings considering the role of feedback and the meaning the informants created from experiencing the laser feedback.

It is important to note that laser lights as a form of non-verbal feedback is unlikely to provide useful information for individuals that do not have knowledge of how to utilize the information. In our previously published training study (5), we implemented a brief introductory period where the non-verbal feedback was combined with verbal instruction about how to interpret the information from the laser lights. Based on the statements from the informants, this period was perceived as valuable and necessary to be able to independently understand and utilize the non-verbal feedback in the following weeks. Of note, none of the informants reported difficulties in utilizing the non-verbal feedback after being introduced to it and having practiced using it for some sessions. These findings are not surprising but highlight the importance and usefulness of including a familiarization period in the start of training where basic information about the exercise and the feedback is given.

Several of the informants indicated that the laser feedback gave them information about their movements they were not previously aware of. Moreover, one stated that she was not confident that she was able to independently sense postural changes during RT. Learning about feedback in RT with the laser light also seems to raise the participants' awareness of the qualities of their movement. To be aware of how one's body is moving is likely crucial for allowing appropriate correction of movements and body positioning (6, 11, 15, 30). Importantly, the informants explained that being visually informed by the laser about their movements helped them in becoming more aware of how their bodies were positioned in space and towards the ground. Specifically, they reported an increased perceived ability to *feel* how they moved, which is crucial for the ability to navigate meaningfully within one's surroundings (31). Following Behnke (6, 12), it is likely that the kinaesthetic sensations, or feelings, were present before the training intervention, and the increased awareness might be a result of the laser feedback assisting in connecting these sensations to specific movements and positions. As one informant expressed this mechanism, she felt that she had to "… see it in order to feel it". It is also important to note that the informants' movements provided a feed-forward to the laser lights, which highlights the circularity of moving and being moved as an inter-affective situation (8). Training with the lasers may occur as described by Sheets-Johnstone (11) as movement in concert or in ways that are harmonious. Related to some informants' previous experiences, they told us about how they did not know how they moved. Going from not being aware of their own movements to becoming familiar with how their bodies move in space represents a considerable change for the included informants.

Another interesting perspective that was emphasized by the informants was the experience that they related to the laser feedback in a seemingly unaware manner following the familiarization period. As one stated, the laser communicates directly with the body. Rather, the awareness seems to become apparent for the participants after the movement is completed, indicating a retrospective sense-making (32) due to the laser not "making sense" before it is connected to a kinaesthetic sensation. In a way, the communication between the laser and the body cannot be verbalised but must be experienced. Yet, the participants described that the feedback caused a change in the movement that they became aware of, which helped them further adjusting their movements. This finding speaks for the idea of inter-kinaesthetic affectivity playing a central role in RT movements. This is further supported by the phrasing many of the informants used when describing how they harvested the information the laser gave them, and how they were able to use and interpret the information to their advantage. They stated that they could respond to what the laser "instructed" them to do based on its' relation to a feeling rather than an explicit instruction. In many ways, these accounts correspond well to previous descriptions of embodied cognition (33, 34). When a person is situated in this specific context and can visually sense the environment providing affordances, they can be directly influenced by the environment and adjust their actions with effortless information-processing (35). In this manner, the

sensorimotor functions are "body-based" (34) and the central understanding of the information provided by the laser is only realized after it has been interpreted by the body.

The informants' unawareness of their own movements in combination with their explanations of the feedback as having an effortless connection with the body may indicate that the visual, non-verbal feedback can be favourable over traditional, verbal feedback for this specific population. As previously described, feedback in RT is traditionally provided verbally by a trainer or instructor during or after the movement. Some of the informants had previous experience with receiving verbal feedback in RT from a trainer. When reflecting on the comparison between the two methods, one expressed that she had experienced verbal ques from an instructor being interpreted in a different way by her than what the instructor had intended. She highlighted that words and phrases can have different meanings for different persons, and that the externally observed movement may not always reflect her lived experience. Trainees must likely be somewhat aware of their own movements and body positions to understand verbal ques from an instructor (1). Conversely, the informants expressed that the laser provides "a direct indicator of what I must work on" that is directly taken up in the body without having to be interpreted or translated from words to action. Rather than being created by one person interpreting the movement of another and communicated back verbally, the feedback from the laser is both created and received by the same body. This likely presents a constant circularity of feedback and feed forward between the training body and the laser lights. Therefore, the information from the laser is both individually tailored and open to an interpretation that has value and can be understood by the receiver. This *open representation* (36) means that the laser alone does not suggest a meaning or give explicit, instructional data. Hence, one can argue that visual, non-verbal feedback says more than a thousand words, but only the ones that can be interpreted in a meaningful way by the trainee are harvested and utilized. Since the informants were originally unaware of how they moved, a feedback method that seems to bypass the awareness and directly communicate with the way they move may be more suitable for this population since it does not require an explicit understanding of one's own movements.

One informant explained to us that she perceived her own focus to be elevated when she lifted heavier compared to lighter loads, such as during warm-up or in the earliest sessions of the training intervention. It is possible that the stimuli from the non-verbal feedback and from her own body are perceived as stronger or clearer following an increase in the training load. This phenomenon might be a understood through the concept of inter-kinaesthetic affectivity (6) in the sense that both the strength of the external stimuli, as well as the degree of bodily awareness by the individual are elevated when the relative loading is increased. Moreover, this statement corresponds to the findings by Spelmezan (3) who concluded that the perceived level of how helpful the non-verbal feedback was may be related to the relative difficulty of the task. Specifically, the researcher reported that very easy tasks made the participants perceive the feedback as disturbing, whereas very challenging tasks made it difficult to maintain a focus on both the task and the feedback. In our intervention study (5), the training load was self-selected in cooperation with the researcher, meaning that the difficulty of the task was challenging, but not too challenging for the participants. Together, the findings from this study in the light of Spelmezan's (3) reports could indicate that non-verbal feedback in RT is feasible and perceived as useful when the loading is relatively high, but within a somewhat comfortable range.

It appears that the time from feedback is given until an adjustment is made can differ between the two feedback methods. While the laser provides constant and immediate information about the movement, verbal feedback is often given after a movement is completed. Our interpretation of this is that recalling the feeling of a movement makes it challenging to associate it with the verbal feedback in hindsight. However, further research is needed to confirm how these experiences can be understood. One reflection is that verbal feedback also can be given during the movement. However, from the perspective of the training subject it would require a longer process of interpretation and require more information-processing compared to the laser lights' feedback. Indeed, one of our informants described the bodily response to the laser feedback as "automatic" in that the laser controls and is in contact with the body directly. One potential benefit from the immediate adjustment following the laser feedback is that one single attempt can provide the trainee with the answer to how a correct execution should feel (if they are able to correct accordingly in the same attempt). In comparison, verbal feedback may promote a more trial-and-error based approach which might not be perceived as useful until the trainer makes the trainee aware of the intention. This can entail a series of several unfavourable executions before the desired movement pattern is obtained, which furthermore can create a frustrating space for both the giver and receiver of the instructions.

It is important to note that our intervention study (5) found no improvement in lifting technique as subjectively rated by three RT experts. However, the participants that received visual, non-verbal feedback improved strength and their self-selected training resistance throughout the intervention without impairing lifting technique. Moreover, the participants only received verbal ques during the first sessions and trained independently from the instructor in most of their sessions. This could indicate that, although not identified by the measurement methods, some development did occur that allowed the participants to lift more weight with improved independence and self-confidence following familiarization with the exercise and the feedback method. The improved perceived safety that the informants describe likely mediated their increase in self-selected training resistance. However, it appears that they understood the laser feedback more as a tool for helping them to avoid errors than for improving their current technique. Further examination of this phenomenon is required to reach a deeper understanding of how the laser feedback might lead to both improved self-confidence and performance in RT.

It becomes apparent that the informants view the laser lighs' feedback as useful and even more helpful than verbal feedback

from an instructor. However, it is important to highlight that they are aware that the feedback does not exist in a vacuum, but as a part of the social setting in the RT context. To create meaning from the non-verbal feedback, they must have some knowledge of both the exercise and the feedback itself, as well as to trust their own bodies and movements. For example, one mentioned that «… it's difficult to learn it (the back-squat exercise) from the laser if you don't have knowledge about the laser. I feel like there must be both for me to learn something". With "both" she refers to the laser feedback and the researcher who provided information about how to understand the feedback the laser provides. The statements from another woman about how the presence of both the lights and the researcher were necessary for the feedback to have meaning for her highlights that this form of feedback has no intrinsic value unless it has been explained for the participants before they start using it. It also highlights the importance of the presence of an experienced instructor that the participants trust in giving them sufficient and correct information about the lasers' use case. Given this initial presence of an experienced instructor, one might assume that the participants' bodies were prepared for the kinaesthetic responses between them and the laser. In other words, the training atmosphere reduced possible stress and perceived pressure to perform the exercise well from the beginning of the training. In contrast to the recommendations by Spelmezan (3), our findings can be interpreted as an argument for an early introduction of automated feedback in the practice. Since the non-verbal feedback might be more open for interpretation, it could allow beginners to explore and develop their own definitions of optimal movements which can later be fine-tuned by the assistance of a trainer.

One intriguing theme that emerged when analysing the informants' statements is that they sometimes describe the development they experienced during the training as relayed to them through the laser feedback and not directly through doing the exercise. It is possible that the lights helped them become aware of how their own kinaesthetic sensations were related to the execution of the training only after first becoming aware of the lights. This further supports our speculation that an exploratory introduction to a new movement might promote bodily awareness. This process could produce an important foundation for further practice if the trainees can have a broader repertoire of sensations that they can assign verbal cues to. Again, their frequent usage of the word "automatic" in their descriptions of how they were moved by the laser is noteworthy. This could indicate that when the laser lights communicated directly and non-verbally with the body, the perceived learning that the informants describe reflected their increased understanding of the feedback rather than of the exercise. Indeed, one informant reflects on this matter and asks herself if "… the body has actually taken it in and can work with it, or if it's the lights that control it (the movement)". When asked to elaborate, she concluded that "I would miss the lights" if she were to train without them and specifies that she referred to the lights giving "answers" to whether she is performing the exercise correctly. These observations indicate that a dependency on the feedback develops after a period of training with the laser lights constantly providing information about the movement. The participants' accounts of their ability to eventually control the lights (feed forward) and comprehend their kinaesthetic sensations regarding their body posture suggest that their movement was gradually transformed into a product of their own volition, rather than a consequence of the feedback they received. Unfortunately, our current data is not able to indicate how this may manifest over time, but this should be explored in future research.

Traditionally, there has been a division between inner and outer stimuli for influencing the movement patterns of training individuals. For example, external stimulus is often provided as verbal instructions or encouragement (37), whereas intrinsic motivation or sensations of contact with the body and movement can be regarded as internal stimuli. To take up external, verbal stimuli, the training individual must process the information that is given to them and translate it into a mode of communication that the body understands and can respond to with movement. Conversely, internal stimuli may be lived and experienced rather than heard and interpreted. By implementing non-verbal, visual feedback, we theorize that the line between the internal and external is blurred, and even erased as the intracorporeal space between the training individual and the laser light is shared and created in unison (38). Indeed, the visual lights are external from the trainee's body, but at the same time they originate directly from them and may be experienced like an extension of their bodies that they can visually observe and take up information from. As one of the informants mentioned, the laser light feedback is comparable to a mirror, but provides clearer indications of right and wrong movements or deviations from the desired movement pattern. Furthermore, the uptake seems to happen automatically and directly, without them having to process the information through thinking *about* the movement. As one of the informants put it "But I never think that, when I see that one (laser light) goes to the side, it's because I have too much weight on one foot. It's more like I don't know which foot, but I know that I must have it equal on both". In this statement she describes the visual uptake of the feedback and how she does not need to understand it to know what she needs to do. The experience she described could be exclusive to this specific method of feedback because it is (1) non-verbal, (2) provided directly and immediately, and (3) tailored specifically to the person's movement (by the person's own movement). Albeit not investigated in this context, it could be of interest for future research to explore in what ways the use of visual feedback can assist trainers and trainees in developing a language that takes bodily experiences as reference points that both the trainer's verbal instructions and the trainee's sensations can be linked to. The phenomenological framework can prove useful in future research into this topic.

## Conclusions

In this study, we sought to explore how non-verbal, visual feedback provided by laser lights was experienced and interpreted by inexperienced females undertaking back-squat

RT. Following our analyses and interpretations, the interview data suggests that the informants perceived the laser feedback both as a useful tool for learning and maintaining qualitatively aligned technique during the training. Moreover, the informants expressed that they had experienced an improved awareness of their own bodies in the context of RT and feel that they can be more in contact and in control of how they move. They explained the progression in their movements as originating in the visual information which they are, over time, able to relate to kinaesthetic sensations informing them about their movements and bodily positions. Following a period of training and familiarization, they report an increased independence and ability to correct movements based on a combination of the feedback and their bodily sensations. Our previously published training study (5) indicated that increased loading could be used without a depreciation of lifting technique or movement quality when the laser feedback was used. To our best knowledge, however, it is still unknown how training with visual, non-verbal feedback affects long-term development and if it produces long-lasting changes in movement patterns. Trainers and researchers can consider using this form of feedback as it seems to be perceived as useful for the participants. Importantly, a familiarization period together with a trainer or instructor seems necessary to introduce both the exercise and how to utilize the information from the feedback. Further research is needed to identify how much emphasis there should be on either the verbal or the non-verbal feedback at different times in the progression of the practice. Hopefully, this paper can assist in the progress of generating adequate concepts and theoretical frameworks to be aware of when developing and understanding RT programs.

## Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors upon reasonable request, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by the research ethics committee at the Faculty of Education, Arts and Sports at the Western Norway University of Applied Sciences. The patients/participants provided their written informed consent to participate in this study.

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## Author contributions

NS, VA, AHS, and TEJS conceived the idea for the study, whereas NS and GHE developed the specific methodology and procedures. NS and GHE conducted the interviews and performed the analyses. NS transcribed the interviews and drafted the manuscript. All remaining authors provided their unique critical reviews of the manuscript based on their specific background and expertise. All authors contributed to the article and approved the submitted version.

## 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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# Utilising the learning in development research framework in a professional youth football club

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Underpinned by an ecological dynamics rationale, the Learning in Development Research Framework (LDRF) has been suggested to introduce methodological possibilities to investigate and illuminate: (i) socio-cultural constraints within a sports organization or club, and (ii), a research gap on the need for a more contemporary framework to guide reliable ways of conducting investigations and designing practical applications. To provide a strong justification for the nature of the fieldwork and methods adopted, we present insights from a 3-year and 5-month study at a professional football club in Sweden that adapted the framework as a central feature of their Department of Methodology for player development. A phronetic iterative approach was employed to analyze the data. The findings highlight the nature of constraints acting over varied timescales, transcending contexts to manifest in other contexts (e.g., practice task designs), influencing events and experiences. This indicated a need to dampen (using probes) the influence of the pervasive organizational "control over context" approaches that were acting as "sticky" socio-cultural constraints, shaping the intentions (in session design) and attention (during practice and performance) of players and coaches. A practical implication is that the LDRF does not prescribe a universal solution to player development. Rather that it can guide how researchers, practitioners, clubs and organisations could challenge themselves to adapt strategies to design contemporary athlete development frameworks within their ecosystem.

KEYWORDS
skill learning, ecological dynamics, ethnography, talent development, affordances

## Introduction

It has been recognized that a sports organisation is part of a complex, multi-layered system, where the social, cultural, and historical contexts are important constraints on the development and understanding of skilled performance (1). Exemplified in the specific social, cultural, and historical traditions of a nation or region, these factors can play an important role in shaping the way coaches design practice and the way athletes engage with learning environments (2). However, sport science research has tended to undervalue socio-cultural and historical factors that influence athlete learning and development, neglecting critical features that have important implications for transferring findings to applied settings (3). For example, a path dependency of seventeenth-century scientific ideas [i.e., the Newtonian/Cartesian paradigm, see (4)] has arguably led sport science to downplay the role of environmental constraints, creating an *organismic asymmetry* (5).

This biased preference for organism-centered explanatory mechanisms, focusing on the "internal mechanics" of the athlete (5), has had an influence in shaping applied research and practical interventions. This has led to a significant body of research applied to sport narrowly focusing on the individual athlete (6), resulting in practitioners and organizations holding an (ontologically) limited picture of the complexity of human learning and development in sport (7).

To counteract the previously mentioned organismic asymmetry in research and player development, ecological dynamics has emerged as a guiding theoretical framework to inform new approaches to research, athlete development and pedagogical practice in sport (8). Drawing on ecological psychology and the theory of constraints on dynamic systems (9, 10), an ecological dynamics perspective proposes that skillful behaviour emerges from the complex and dynamic interactions of an individual's continuous adaption to surrounding constraints, which change over micro- and macro-timescales (8). Here, it is implied that skill learning occurs in the midst of ongoing developmental changes within specific socio-cultural contexts (2). This perspective highlights the potential for a myriad of possible complex, unpredictable and ill-defined challenges for sport organisations when seeking to implement an athlete development framework (3).

A growing body of research encompassing sociological and ecological approaches to coaching and athlete development are highlighting a need to radically broaden our ways of knowing [e.g., (11–13)]. Indeed, more recent research has sought to highlight how environmental factors contribute to the development of expertise (see (1)) (14, 15). While these studies have proven adept at providing a descriptive account of the current context in which athletes develop, there seems to be little or no intention to initiate change or evolve practice in that context. Considering the potential for a myriad of possible complex and ill-defined challenges in the realm of talent development, there is a need for an approach that will guide reliable ways of conducting research, and designing practical applications, that reveal insights on the socio-cultural complexities and sub-system interrelatedness of athletes and environments. Until recently, no specific research framework has been proposed to help sports clubs and organizations with this endeavor. In response, O'Sullivan and colleagues (2) introduced the novel Learning in Development Research Framework (LDRF), a deeply contextualised, transdisciplinary approach to action research that is founded in ecological dynamics and the Skilled Intentionality Framework (SIF). It is our intention to advocate for and later outline, how the LDRF, refined during the first author's PhD thesis, was utilised to guide an iterative, ongoing cycle of research and action, and support the evolution of player development framework at a professional football club in Sweden.

## The learning in development research framework

Utilizing novel ways of knowing, coupled to an ecological perspective (e.g., the theory of ecological dynamics and the Skilled Intentionality Framework), the LDRF can be utilized to guide both research and practice within specific sport organisations (2, 13). In this paper we exemplify how socio-cultural practices (task designs) in a specific player development environment has adapted to, and is constrained by, social and cultural forces and how interventions, system probes, were devised to probe the system.

The LDRF focuses on ecological approaches that can illuminate the interplay between socio-cultural constraints and affordances for skill learning within a form of life. Wittgenstein's (16) notion of a *form of life*, consisting of values, beliefs and practices that continually shape how we live (17), helps us to comprehend the myriad of socio-cultural constraints that can influence an athlete's responsiveness to available opportunities for action. For example, a form of life may define dominant ways of *doing* in a society, community or organisation (17) and can be conceptualised as something that is deeply acculturated, socially accepted, and often taken for granted. Demonstrating the influence of specific socio-cultural and historical constraints in the development of expertise, current forms of life identifiable in sport could be soccer in Argentina (la nuestra) and Brazil, skiing in Northern Europe and rugby union in New Zealand. These examples provide insights into why certain performance styles are developed in certain regions and why they are valued. This notion also appears in the Skilled Intentionality Framework (SIF), a conceptual framework that, through utilizing ethnographic strategies to generate knowledge, directly couples forms of life to the relevant fields of affordances (opportunities for action) that influence skilled action [see (18)].

Within an ecological dynamics rationale, it is proposed that an individual perceives the environment in relation to its functionality, its meaningfulness detected in information for affordances (9). Affordances are properties of the individual-environment system that do not cause behavior, but constrain it (9), helping us avoid problems with defining skill development as an internal characteristic of an individual or of the environment. Foregrounding the notion of sociomaterial entanglement, the SIF highlights how affordances are not just passively situated in isolation in the materiality of immediate behavioral settings of a sports organisation (training session, competition). Rather they are deeply entwined within a more culturally encompassing, socially and historically developed constellation of practices and forms of life (18). Constitutive sociomaterial entanglement is the ontological notion used to explain the active, dynamic and transdisciplinary reality of the environments in which we live and develop. It proposes that the ways which we live (forms of life), the practices we partake in (sports training methods), the affordances we perceive (invitations for action in these contexts) and the skills we develop (e.g., passing, dribbling) are constitutive relations and aspects of a holistic system that continuously form each other (2, 18). So, while a form of life can influence the way sports organisations implement their athlete development frameworks, the SIF helps illustrate the extent to which socio-cultural-historical constraints in a form of life (e.g., a football club) shape the intentions of players, soliciting some affordances over others and directing skill learning in development (2).

To elaborate on these ideas, it is useful to consider data from a 3- year and 5-month study in a professional football club in Sweden that has adapted the LDRF (see **Figure 1** for graphic outline) as a central feature of their Department of Methodology (DoM), to support the evolution of a player development framework. As outlined by O'Sullivan and colleagues (2), we first endeavour to understand the "practical situations" within which behaviour emerges within this organisation. To achieve this, the SIF, foregrounding aspects of qualitative inquiry (i.e., ethnographic) are introduced to unpack and enrich our understanding of the relations between coaches behaviours, the socio-cultural and historical context, and players' intentions/ interactions within a relevant field of affordances. As the intention with the LDRF is to initiate change and/or evolve practice, the impact of being immersed in a local setting, utilizing the SIF, is complemented by an action cycle that aims to implement its findings. Considering that macro-level socio-cultural constraints evolve over the years and can be difficult to directly influence, we illustrate how DoM devised interventions to probe the system (17) at the micro-level of on-pitch coaching pedagogy. For instance, respectively amplifying or dampening helpful and unhelpful aspects of form of life that are acting as socio-cultural constraints on coaches' intentions (in session design) and players' attention (during learner interactions in the sessions themselves). A simple example of this could be damping language that amplifies ideas and narratives associated with socio-cultural constraints e.g., referring to under nine football players as elite (see (21).

Highlighting the highly iterative and integrated nature of the LDRF, as findings are being implemented through system probes, in tandem, the next research cycle (utilizing SIF) seeks to capture the evolving sociomaterial environment as it persists and changes, connecting the research back into the next action cycle. More directly, while ethnography supports long-term immersion in a local setting, it can have limited impact (19). When complemented by action research, ethnographic research is more "likely to be useful and usable by those working on the ground … and to address the identified gaps between research and the ability to implement its findings" (23). This combination of ethnographic strategies and action research can offer a deeply contextualized and continuous analysis and assessment of a form of life in a particular ecological niche, even while findings are being implemented [for a more detailed discussion see (2)].

We contend that emphasizing the enrichment of a reciprocal and functional relationship between athletes and environments forming complex, interconnected systems (24) (e.g., ecological dynamics), can provide a valuable theoretical underpinning for action research (25). In turn, action research can provide a valuable methodological approach to the critical and practical study and evolution of complex systems in contexts like sport, work and education (25). It is this opportunity of analyzing the phenomenon in greater depth each time (highly interconnected research-action cycles), illuminating the influence of a form of life at the microscale of development (i.e., how players engage with affordances for skilled behavior) and support interventions to probe the system (e.g., player development environment) that characterises the Learning in Development Research Framework (LDRF) in practice.

The Athlete Talent Development Environment (ATDE: (1)) was used as a framework for data collection and organisation. Acknowledging Feddersen and colleagues' (2021) (26) work on the limitations of the ATDE, we extended its use, emphasising the ecological level of analysis by embracing a Gibsonian perspective (9), with particular emphasis on (17) relational view of affordances in the SIF. Here, affordances are not just passively situated in isolation in the materiality of immediate behavioral settings of a sports organisation (training session, competition), but are entwined in a particular way of life (18).

Rietveld and Kiverstein (17), extended the more traditional *action-scaled* view on affordances, suggesting that affordances are not simply action opportunities offered by the environment but are dependent on the "abilities available in a particular ecological niche". To illustrate how each sporting context is contained within its own form of life, which may amplify or dampen player engagement with some affordances, it is worth considering Winner's (27) rich narrative of Dutch football. As a mirror expression of its culture, architecture, landscape, history, politics, geometry and dance, the idea of "total football" was built on a

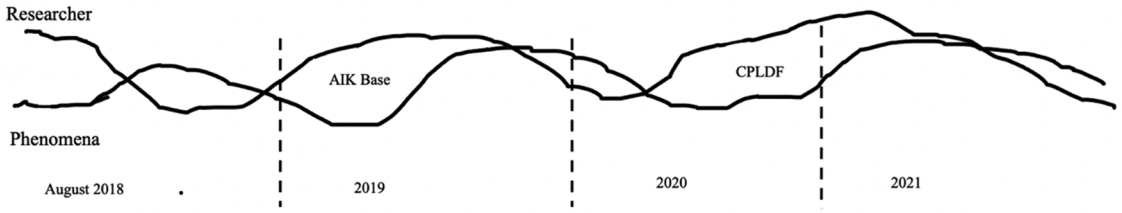



FIGURE 1
The LDRF foregrounds research that is "undergone" longitudinally through attentive and responsive participation. How the researcher comes to know the landscape, and how they learn to correspond (probes), is through dwelling. The graphic highlights how the LDRF was utilized, through an ongoing ethnographic inquiry punctuated by probes (AIK Base and Contemporary Player Learning in Development Framework) delivered at the micro-level of on-pitch coaching pedagogy. Inhabiting a place in-among the coming-into-being of the phenomena (as it evolves and persists), encourages a perceptual attunement to its ebbs and flows, and what the phenomena have to share directly with the researcher. Graphic is adapted from Woods et al., (2022).

new theory of flexible space, creating space where there was not any before[1] (28). The theory of affordances embedded in forms of life can provide a powerful rationale to help practitioners consider the socio-cultural constraints in specific environments, which may shape expectations and beliefs on coach and athlete behavior, performance, development and learning.

A central aim of the LDRF is to shift the focus of athlete development research away from just the individual athletes and towards understanding behavior at the level of interactions between a performer and their performance environment, both continuously shaping each other (29). The SIF provides the philosophical foundations for this shift as described by the de ontology of constitutive sociomaterial entanglement (18). This world- view aims to demonstrate the extent to which the ways we live (forms of life), sociocultural practices we participate in (e.g., football), opportunities for action (affordances) and the skills we develop exist as, and exhibit, a constitutive relation where practices and affordances do not admit of a prioritization (2, 18, 30). For example, referring to Winner (27), it can be suggested that the Dutch playing style of "total football" evolved, within a specific socio-cultural context as players' perceptual systems and effectivities developed in, interaction with an intention to create a diverse range of passing and dribbling opportunities/affordances to exploit space.

The SIF can make a profound contribution by providing a perspective on the extent to which athlete development environments are sociomaterial and constitutively entangled within broader macro contexts and structures (1, 6). By connecting social and cultural aspects of life with the skill development of athletes, the SIF helps to demonstrate the resonance between a form of life and the relevant field of affordances that stand out in their training sessions. This resonance has been explained as the value-directedness of player-environment intentionality [see (30)]. An ecological account of these dynamics is reflected in this paper, where for example, we outline how expectations that embody a cultural inheritance of player compliance towards prescribed coaching methods can shape a value-directedness toward affordances that can partially realize that value [(26); for an example see (2)]. Overtime players that are exposed to these practices may develop unskilled intentionality (coordinate with only a narrow range of affordances (30).

The SIF significantly contributes to the way one views an ATDE by outlining the extent to which the intentionality of any organism-environment system is an interdependent and constitutive relationship (18). In other words:

> Intentionality characterizes the system, not just biological organisms within the system. Thus, intentionality in the sense of value-directedness characterizes environmental structures [i.e., a form of life/ATDE] and processes [i.e., sports training methods] as much as it does the organisms [football players] who shape and are shaped [e.g., skill development] by those structures and processes. This implies that values are necessary constraints on both the constitution and the selection of affordances [(26) text in brackets added)]

We must aim to comprehend, and attend to, the contextual complexities of our situations and co-create practices that amplify and dampen helpful and unhelpful aspects of our form of life. Aligning with North and colleagues (32) warning against the uncritical application of good practice ideas from other successful countries, this approach recognizes that there can be no "copy and paste".

# Materials and methods

## Background and context

Allmänna Idrottsklubben (AIK) football club in Stockholm, Sweden provided a rich and unique socio-cultural and historical backdrop for this study. AIK youth football engages around 1,700 players between 5 and 19 years. In April 2017, after an in-depth, rigorous analysis and review of its operations at child-youth level, the club disbanded its early talent selection policy and set about investigating possibilities to build a player development framework guided by three strategic goals: (i) to support the well-being of the child; (ii) to follow supporting documents from the United Nations Convention on the Rights of the Child and Swedish Sports Confederation and (iii), secure the promotion of more youth players to participate in the under 16, under 17 and under 19 years teams and in the clubs senior teams.

In January 2018, the newly formed AIK Department of Methodology (DoM), consisting of professional coaches and sports scientists, was introduced in the club's yearly planning document. To support the club in its endeavor, the LDRF was adopted by the DoM to investigate the current athlete development environment and to inform present and future possibilities of evolving practice and player development.

## Access and role clarification

The study was given institutional ethics approval[2] and all interviewees provided informed consent prior to participation. The first author gained access due to his dual role of practitioner-researcher and member of the DoM, as part of their terms of employment at the club. The potential for role conflict throughout the research process due to this dual role was recognized. For

[1]https://www.thoughtco.com/polders-and-dikes-of-the-netherlands-1435535

[2]Sheffield Hallam University ethical approval (Converis ID: ER5584185)

example, it could be perceived as a position of authority over various staff members, having an influence on the data collection process (33). However, the value the club placed on the importance of researchers and coaches collaborating in practice was consistently reiterated by the head of youth development at the twice-yearly coach and parent education meetings.

## Research design and procedure

To illuminate the interplay between socio-cultural constraints and affordances for skill learning, we present a 3-year and 5 months inquiry (see **Figure 1**) to illustrate how a professional football club adopted the LDRF as a feature of their DoM. Ethnography, as a central feature of inquiry in the LDRF, can broaden the scope of ecological psychology by providing methods that can theme the patterned practices of a form of life in an organization and provide insights into athlete-environment intentionality (13, 18). Ethnography is founded on the collection and documentary of data (audio, video, field notes, interviews) predominantly relating to what Gibson (34) theoretically refers to as secondhand *knowledge about* the environment. Comparatively, *knowledge of* the environment is reflective of embodied-embedded knowledge developed by, and exemplified in, activities behaviour that enhance the coupling between perception and action (34).

This epistemological distinction is apparent in the differences between *knowing about* the environment through indirect perception of information (9) that has been produced and documented by another person (typical of coach education courses). This form of knowledge embodies the manifestation of an external relational but "generalised" environment. In contrast, *knowing of* (9) the landscape's invitations to act directly engages with perception and action (i.e., attuning to information) in a specific performance environment (35). Araújo et al. (29) proposed that gains in direct perception (e.g., gaining knowledge "of" one's environment) may be mediated through communication *about* the environment. Information collection via ethnographic endeavour can be used to create themes that can uncover broad socio-cultural constraints that influence the value- directedness of player-environment intentionality which, in turn, frames the perception-action couplings for affordance utilization (13).

To understand how players respond to affordances offered by the material aspects of the environment and by other people (in practice and competition), it is important that we understand the practical situation in which behavior occurs (18). Embedded here is the appreciation that training sessions, competitive games do not take place in a socio-cultural vacuum but are deeply entangled within meaningful contexts of a broader societal form of life (37). The ethnography (utilizing the SIF) employed in this study allows for a rich exploration of the extent to which social and cultural patterns of life are embodied in the way football is played and skills developed (18, 30).

As the intention with the LDRF is to initiate change and evolve practice in a specific athlete development environment, the impact of being immersed in a local setting was complemented by an action cycle that aimed to implement its findings. Here, with the support of a DoM interventions were devised to probe the system (17), to amplify or dampen socio-cultural constraints shaping the form of life. Ethnography provided insights into the form of life, and as subsequent probes were implemented, helped to capture real-world changes in practice and connect the research back into the development of a player development framework.

To summarize, in order to engage with the sociocultural complexities and sub-system interrelatedness of athletes and environments, we have outlined the relationship between socio-cultural constraints, player-environment intentionality and fields of affordances. We have argued for a combination of ethnographic strategies and action research to offer a deeply contextualized and continuous analysis and assessment of a form of life in a particular ecological niche, even while findings are being implemented. We will now briefly highlight the ethnographic strategies of inquiry that help us link a zoomed- out view on the form of life to a zoomed-in perspective on concrete situations (micro systems of practice). We will then proceed to illustrate how the LDRF informed present and future possibilities of evolving practice and player development at AIK youth football.

## Historical contextual analysis

It has been argued that to better understand athlete development in and through sport, culture and context matter most (29, 38). A contextual historical analysis (available as extra material) has been proposed as a productive approach for investigating the socio-cultural contexts in which phenomena historically unfold (12). This lens provided insight into the overarching ecological context (macrosystem) that conveys the information, ideology, and values that influence organizational structures (i.e., roles, responsibilities, tasks) and events in the embedded microsystems (i.e., coaching sessions) where athlete development takes place (38).

Information was retrieved from various documents and media such as books, coach education material and articles (both printed and electronic) sourced from the Swedish Football Association (SvFF), Swedish Sports Confederation (SSC), AIK football club and various newspaper articles relating to child youth sports in Sweden and the development of Swedish society, which the first author translated from Swedish to English. The most important sources were The Nordic Sports Forum archive[3] on Swedish sports, sport policy and sports studies, the Swedish Sports Confederations document bank[4], the Swedish Football Association's (SvFF) coach education material, the Center for Sports Science (CIF) archive[5] and various national media

[3]https://idrottsforum.org/merom/svidropol/

[4]https://www.rf.se/bidragochstod/Dokumentbank

[5]https://centrumforidrottsforskning.se/kunskap-om-idrott/rapporter

archives (e.g., Dagens Nyheter[6] archive from 1864 to 2022). These sources contributed towards illuminating some unique social, cultural, and historical constraints that informed observation and interview methods and what data should be collected in the field.

## Observation

Unobtrusive observation provided the opportunity to observe behaviours and actions, sociocultural practices and events (39). Participant observation does not require a specified group of participants (33), and initially offered the opportunity to follow the participants across several contexts (training, match day, meetings, informal office conversations). These types of public observations pose no threat to neither the observer or the observed (33) and people are not identifiable within the data (41).

During the first action cycle (probe), the first author adopted the role of observant participation (35) to support on-field education, enabling deeper insights into the functioning relationships, rules and peculiarities of the place and people, all of which are fundamental to ethnographic research (43). Field notes included text, audio and video recordings, reviewed and categorised into a detailed log of field notes by the first author within 36 h of events occuring (44). This promptness helped to inform the development of the data and how the first authors' emotions, experiences and assumptions might have influenced the creation of knowledge (46). For example, often on the train back from training the first author would begin to edit the filmed training session, while making some additional notes to be worked on the next day. Video clips from practice sessions were edited and shared with coaches on a regular basis to initiate further discussion and reflection.

## Interviews

Informal conversations occurred spontaneously in the context of participant observation (46). For example, this included, speaking with coaches before and after practice sessions, at club educational events or during an impromptu "fika"[7] at the office. A feature of these unexpected situations and chance encounters is that they can contain less asymmetrical power relations than more structured interviews (47). Participant consent was sought from key club colleagues and leaders, who are represented (with pseudonyms) but not identifiable within the data (41). After purposeful sampling of participants, ten semi-structured interviews were carried out to probe for richer information. The selection criteria were that the participants must be an active coach, must work actively in the setting and have attended the Swedish Football Association coach education courses. Six coaches held a UEFA A coaching license, one held a UEFA B, and three coaches had a level one (C-Diploma) qualification. The interview guide was inspired by Henriksen (1) and the first author's knowledge of youth football in Sweden. A 3-part guide for semi-structured interviews was formulated. The first section sought to elucidate the participants' experience of playing football as a child (e.g., "What did a typical training session look like when you were a youth footballer?"). The second section aimed to explore participants' entry into the coaching world and their experience of coach education (e.g., "were the type of practices promoted on these coach education courses evident in AIK?"). The third section explored participants' experiences since AIK took the decision to restructure its youth football in 2017. As a fluent speaker, the first author carried out the interviews in Swedish, later transcribing them into English. Interview lengths varied from 30 min to 45 min.

Throughout the study the first author returned to the interviewees to gather more data, where informal interviews and conversations, filming and assisting during training sessions, helped me to achieve more depth and comprehensiveness, increasing contextual depth in the research (48, 49). Swain and Spire (47) highlighted how the role of informal conversations in qualitative research is contested but also relatively neglected. However, considering the deeply embedded nature of their dual role of practitioner-researcher, the first author regarded informal conversations as opportunities to hear people "tell it as it is" in an everyday context (50), potentially providing "context" and "authenticity" that can enrich the data (47). Indeed, Hammersley and Atkinson (50) further argued that these interactions or conversations are still a type of interview, in the informal sense. Informal conversations can be seen as a useful way to establish a rapport, gain trust, reduce the imbalance between the researcher and participant and get closer to the reality of individuals' experiences, perceptions and beliefs (51, 52).

## Data analysis

A distinct feature of many social science inquiries has been the sequential nature of data collection, analysis and writing up of studies (45). However, in this study a phronetic iterative (a cycle that repeats) approach was utilised, alternating between emergent emic (e.g., " a nerve") readings of the data and an etic (e.g., coach centered coaching) use of existing models and theories, was used to analyse the findings (45). Analysis alternated back and forth between: (1) data generation, (2) scrutinising emergent findings from the data, and (3), consulting existing theoretical and conceptual frameworks underpinning this case (i.e., ecological dynamics) (45). The ethnographic process supported the commencement (during research-action cycles) of data

[6]https://arkivet.dn.se/

[7]https://www.bbc.com/reel/video/p0bmzygz/the-swedish-tradition-that-can-make-you-happier-at-work

analysis to begin with data generation (54), helping us to identify promising directions of research (45). Initial analysis began with a formal process of interpretation, a descriptive "primary cycle coding" or "open coding" (45), where descriptive and basic codes were developed. Examples included, "focus" and "everything in order/ordning och reda". During data collection, the Department of Methodology, which included the second author, regularly met in various constellations, as critical friends, to offer different perspectives, reflexively acknowledge multiple "truths" (55) and discuss emerging interpretations. This helped in determining how the initial primary cycle codes might be developed in the process of "secondary cycling". In the secondary coding cycle, the first author began to interpret, organize and synthesize codes (45). This move towards more "focused" coded themes required interpretation and theoretical considerations. In particular, the first and second authors' understanding of theory and literature provided a foundation for interpreting and building theoretical explanations, as well as informing new lines of inquiry (45). For example, we can endeavour to devise an umbrella code, a larger hierarchical code called "coach centered pedagogy" that can encompass smaller primary codes like "focus" and "everything in order". Fundamentally, this iterative approach to data generation and interpretation informed the refinement and development of system probes and helped capture the evolving sociomaterial environment as it persists and changes, connecting the research back into the next action cycle (probes).

We turned to Henriksen's (1) adaption of Bronfenbrenner's bioecological model (56), the Athlete Talent Development Environment (ATDE) to assist with the interpretation of themes. The AIK ATDE (**Figure 2**) was used as a formative model for data collection, organisation and presentation of themes, that signifies their context (e.g., macro or micro) of origin or significance [see (13) for details].

## Qualitative rigor

Considering the potential subjectivities, the first author brought to the research process and the writing of the paper, they took steps to be reflexive and sincere in making sense of the data and drawing plausible conclusions (57). The first author's expertise in youth sport and coach education, both nationally and internationally, brought unique insights into the underlying meaning of the sociocultural factors on skill development. For example, the first author gained their UEFA B coaching license in 2011 and UEFA A coaching license in 2013, both from the Swedish Football Association (SvFF). From March 2015 until June 2018, they worked as a head coach educator in the Stockholm district, delivering the first two levels of the new SvFF education courses (launched 2014).

This dual role implied prolonged embedded engagement, dwelling in the context of the phenomena, which can promote accurate and truthful depiction of the participants' lived experience (58). The third author's qualitative research experience and the DoM acting as critical friends, contributed to the reflexive process (59). Indeed, a specific feature of this study was the first author shifting from participant observer to observant participant (during on field education). It could be argued that the first author had succumbed to "going native", an occupational hazard with ethnography (60). However, Moeran (35) argued that this shift enables the researcher to gain access to information and knowledge that is otherwise available only to insiders, and that the very richness of the data collected and interpreted from observant participation will always overcome this disadvantage. This view aligns with the transdisciplinary approach central to the LDRF, encouraging the researcher to engage directly with the phenomenon, opening unique lines of inquiry.

# Results and discussion

We now illustrate how the LDRF was used to illuminate the relations between coaches behaviors, the socio-cultural and historical context, and players intentions/interactions within relevant fields of affordances. Expanding on, and refining the work of Vaughan et al. (13) we focus on the pedagogy of practice in the microenvironment and zoom out to consider the path dependent influence of these socio-cultural constraints on practice. This complimentary perspective presents a new set of data gathered within AIK's ATDE (see **Figure 2**), enriching our interpretations and guiding practical interventions conceived as system probes (17). Interventions conceived as system probes aim to skillfully amplify and/or dampen helpful and unhelpful aspects of forms of life, often these aspects can be characterized as socio-cultural constraints within the framework of Ecological Dynamics (2, 11, 13).

The meta theme "control over context" is presented in the microenvironment but represents a coherence of data, illustrating the cascading influence of (value-directed) themes throughout cultural sub- systems (national culture, sports culture, football culture). This helped create a context that led to the emergence of "context-dependent" constraints (61) (e.g., types of task designs, development pathways, expectations), shaping the value-directedness experienced by players.

We will now exemplify this idea, presenting data highlighting a value directedness relating to the club's microenvironment as well as the broader football culture in Stockholm. Value-directedness is an important aspect of player-environment intentionality (intentions) that shapes intention and guides attention toward certain affordances (2).

## Status and performance anxiety

> I am with Vincent (academy coach) watching the boys 2008 academy training. Parents are anxiously peaking over the closed off 7 a side pitch, while standing on benches in the adjacent children's playground. Something happens and one parent looks up to the night sky, while the parent next to him stares at him and opens his arms, then drops his head and shakes it. The 2008s are the last group to go through the

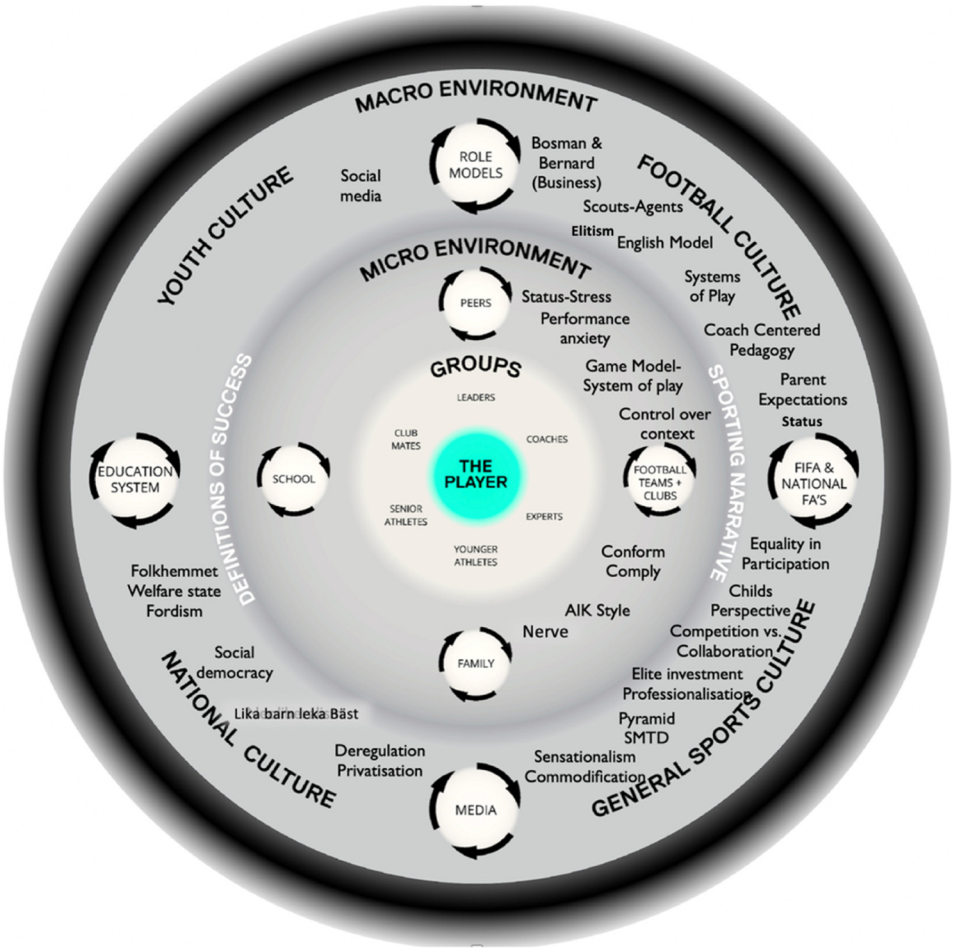



FIGURE 2
AIK ATDE used to organize and locate the data within a broader ecological context. Themes are embedded in relation to the environment/context (macro or micro) in which the data emerged and cohered.

> early academy selection before AIK raised the academy age. It was in the local newspaper Mitt i Solna, that AIK head of youth development Leif Karlsson, explained the reasons behind this decision was to "dampen the emphasis on child-youth football being about children being assessed[8] "[Document analysis: Mitt i Solna article: AIK höjer åldern för start i akademilagen, June 2017 (62). Translated from Swedish]. Indeed, I recall an article I read on the Swedish football associations (SvFF) homepage[9]. It referred to how "youth football in Stockholm is the most stressful and unhealthy in the country" [Document analysis: Fogis, September 2017 (63). Translated from Swedish].

> With the end of the season approaching in two months, and an imminent selection/ de-selection process approaching, the intensity is quite high. The last part of the session seemed to be a game of constant transitions. The early part of the session was a lot of repetitive predetermined passing patterns followed by 1v1's with no consequence (once the attacker lost the ball the 1v1 was over).

> Vincent: This is more like a tennis match

> Mark: The coach seems to be willing them on, tempo! tempo!

> Vincent: This, I guess is what performance anxiety looks like coming up to the end of the academy season. They are competing against each other, even when in the same team, instead of collaborating to make each other better.

(Field note: Informal conversation, September 21st, 2018).

These results reinforce the findings of Vaughan and colleagues (13) by demonstrating ways in which performance anxiety can emerge from a value-directedness towards interpersonal

[8]The traditional democratic values of Swedish sport, namely equality in participation and a child's perspective.

[9]https://fogis.se/arkiv/startsida/2017/09/fritt-spelrum/

competition, amplifying opportunities and behaviours that maintain or protect social status. However, these types of observed behaviours also evidence how, shaped by specific socio-cultural constraints, the structure of development pathways and implemented pedagogies went "hand in glove". This close relationship between pedagogy and player development pathways was further highlighted in the coach interviews, as exemplified by Coach A:

> You see when I began [2011], there was a little nerve that influenced pedagogy. You were forced to have results even at 9, 10 years. A lot of decisions were pre-decided – very clear predetermined patterns which we also practiced very hard in training

The description of a little "nerve" that influenced pedagogy, is indicative of an anxiety and expectation (e.g., results) that cascaded through organizations and structures, amplifying ideas associated with early elite investment and selection de-selection [Standard Model of Talent Development/SMTD, see (64)]. The SMTD, is characterized by early selection into exclusive training programs that often promote hyper-specialization and result in eventual deselection (55, 76). Indeed, this model was a central feature of AIK youth football between 2009 and 2017 where children were "selected for the youth academy one year at a time" [Document analysis: AIK Verksamhetsplan, 2011 (66). Translated from Swedish].

Coaches maintained their status through results and adopted deterministic methods in training and games to control future outcomes and limit unpredictability. The same "nerve" also emerged in parent behaviour, where ideas of linear causality in task designs (limit unpredictability) and "nivåindelning" (the best playing with the best), appealed to an emerging parenting style, a form of "monitoring" to ensure exclusivity with their child not having to encounter too much resistance and problems in their development (67). This is captured in the theme 'lika barn leka bäst' (alike plays best with alike), a commonly used cultural phrase that could convey the idea that children of the same ability should only play and train together. "Lika barn leka bäst" is categorized within a single theme in connection to the national culture but transcends across three themes in the general sports culture (SMTD, Elite investment and Competition v collaboration) and two themes in the football culture (Elitism, Parent expectations/status) manifesting as a form of exclusivity to maintain control, promoting conformity and compliance in the microsystems of practice. When projected onto youth football this phrase, part of the vernacular in and around youth football, could amplify a value on early selection practices associated with the SMTD that were fast becoming a continual pervasive practice in Swedish youth sport (55).

## Lika barn leka bäst

> Mats a parent of one of the young players (9 years old) approaches me. At a club parent meeting, he let his opinion known about AIK removing the early selection model, saying that the club will "lose the best players to other clubs if we don"t select early" (field note 06-11-2018). He was very clear about the need for the best to train with the best. Arne, who coaches this group, had mentioned to me that he had a few parents that wanted "nivåindelning" (splitting the kids into cemented ability levels). His feeling was that "this is about winning games for their own child". (Field note: Informal conversation, February 13th, 2019). Once again, Mats emphasises the point he made about the need to select the best with the best.

> Mats: We call this "saft och bulle" (children's soft drink and buns) training. It's better to split the group into those that are more motivated and those who just want to play. (Field note: Informal conversation, February 14th, 2019).

Interviews further highlighted parental expectations relating to how young players' learning, and development "should look" in practice. As highlighted by Coach H.

> Through a lot of years in football. My feeling is that parents who don't have proper insight into development, they like the look of organisation. They like the look of control, which is easy to get because you can put them in a line and do a passing drill and for someone who doesn't have insight, it can look very, very good. You also get an effect from that very, very quickly and the players can look quite good, quite quickly for doing stuff like that.

Coupling observations to the explanations of coach A and coach H, we can appreciate how a "nerve", symbolic of the broader intentionality of a form of life, has impinged on coach intentions when designing and delivering training sessions. This broader intentionality is further illuminated via document analysis relating to a congruence of entangled themes ("status", "SMTD" and "elite investment, professionalisation, adultification") that sit in tension with themes relating to the democratic values of Swedish sport ("equality in participation" and "child's perspective"), in the Aftonbladet newspaper it was reported that:

> There is currently a professionalisation of Swedish youth football with foreign big teams, child stars used as advertising planks and agents who shadow football pitches with money in their eyes. The ideals that Swedish youth football movement is based on has been split in two. On one side are international big clubs, elitist academies and money-hungry agents who have turned sports into a market and children into consumers and products. There is an evolving culture of status among parents that have a "high performing child".

[Document analysis: Aftonbladet article: Blivit status att ha ett presterande barn, November 24, 2019 (68). Translated from Swedish]

> It can be suggested that these tendencies, a system intentionality/value-directedness (towards early professionalization) that characterize environmental structures (organizational structures within an ATDE) and processes (training sessions), mirror those from broader macro levels beyond Stockholm and Sweden. For instance, the "Bernard case" [see (69)] in 2010, a follow up to the Bosman ruling, had helped to frame youth football as an economic activity, encouraging the training of young "talented" players as a form of "processing" human capital investment. This arguably contributed to the legitimisation of a player development system underpinned by the notion of "early elite investment" in young "talented" Swedish footballers, where young children are grouped by ability into an "elite" group (lika barn leka bäst). Indeed, it was sports psychologist Johan Fallby that described a "distorted system" in Stockholm youth football, one driven by agents and money and "a strong culture based on anecdotal evidence that early selection works".

[Document analysis: Expressen article: Den allvarsamma leken—vem är det som inte får vara med? 31st October 2018 (70). Translated from Swedish].

We are moved to propose that this emergent distorted system in Stockholm youth football was shaping and amplifying ideas and expectations as to what young players learning in development in youth football should look like in practice. Coaches adopted deterministic approaches under the assumption that inviting players to interact with a narrow range of affordances could provide the mirage of "control" and improve learning and performance, which in the footballing form of life, was associated with results. One way to limit unpredictability regarding results was to have an early selection of the best children with the best. This value-directedness toward control over context, through limiting unpredictability aligned with a deeply rooted path- dependent coach education form of life and promoted a pedagogy that had deep innate aversion to uncertainty and ambiguity. The main problem is that this reductionist approach deprived children of opportunities for skill adaptation, a fundamental basis for motor learning.

## Coach centered pedagogy—a path dependent coach education form of life

Practices prioritized in Swedish Football Association (SvFF) coach education until 2014 (coach education was reviewed) were underpinned by a culturally dominant planning paradigm (e.g., specific themes, predetermined coaching points), predetermined passing patterns and the notion of "optimal" technique, enhancing player compliance by using explicit corrective feedback. These practices highlighted a cultural-historical inheritance that had a cascading influence on the type of practices promoted and appreciated in youth football. This approach can be traced back to the 1970s, when the pedagogical legitimacy of SvFF's "Swedish model" (based on the West German model) was being questioned by the successful sporting results and the seemingly more professional nature projected by the "English model" (introduced to Sweden by professional coaches Bob Houghton and Roy Hodgson). The English model promoted a "teacher-centered" pedagogy, where the coach had the overall picture of how the game should be organized and the players needed to comply and internalize the systematized knowledge about football performance that the coach promoted (60).

Exemplified in the intricacies of the "technical register" (coaching folder and video archive of 31 films[10], see footnote), these ideas dominated coach education until 2014. Coach H elaborates:

> It [technique register] was almost like a workbook on every type of isolated technique which should be used in football. We [the coaches on the course] were doing sessions on tackling [theme]. And we were standing in lines. The first in line ran towards the ball and tackled, kicked the ball, and we were told [by coach educators] how to do that. So yeah, it was, yeah, wasn't good, a lot of instructions, a lot about telling players what to do.

The interviews highlighted the role of the "technique register" as a "gold-standard textbook" of ideal movements, promoting a reliance on external agency (i.e., high levels of instruction and feedback) in coach education, and a reductionist and mechanistic attitude towards practice and performance. This perspective contributed to the amplification of a coaching culture that attempted to control future outcomes, shaping beliefs and expectations, while influencing the formation of practices at the club, as summarized here by Coach G: "The technique register, and its micromanagement, was absolutely seen in AIK, in the everyday practices."

Highlighting a system capture (doing things the way we always have done them), coaches were following how they have been coached or complying with the approaches of more "experienced" coaches. Here Coach C reflects on his early years at the club as an assistant to more "experienced" coaches.

> When I started coaching, at the beginning, I didn't reflect on this [coaching like how I was coached]. I did isolated training. My first year, 2016, was with XXXX. There were some drills that were A to B to C passing, and you must do this technique. Not very representative. A lot of go, go, go and this is how we do it, this is a good drill as it goes quickly. It looked good, organised, it gave a little boost, but I never felt it gave much really.

The idea of "it looked good, organised", aligned with cultural expectations of what practice should look like. A consequence of

[10]https://www.youtube.com/watch?v=U9UGWHQX9-c

this continuous reinforcement loop was the culturally resilient belief, that greater stability and consistency in match performance is related to practising repeatable movements or patterns, Coach B refers to how this belief was evident in the more "theme-driven" game-based designs that was limiting player engagement with affordances.

> Yes, even now when they say to players that we must work with switching the play [theme], players just pass the ball from side to side all the time because this is what the coach thinks that they must do and the players' understanding is limited by the idea that they must switch the play, but they will do it so that it will look right for the coach.

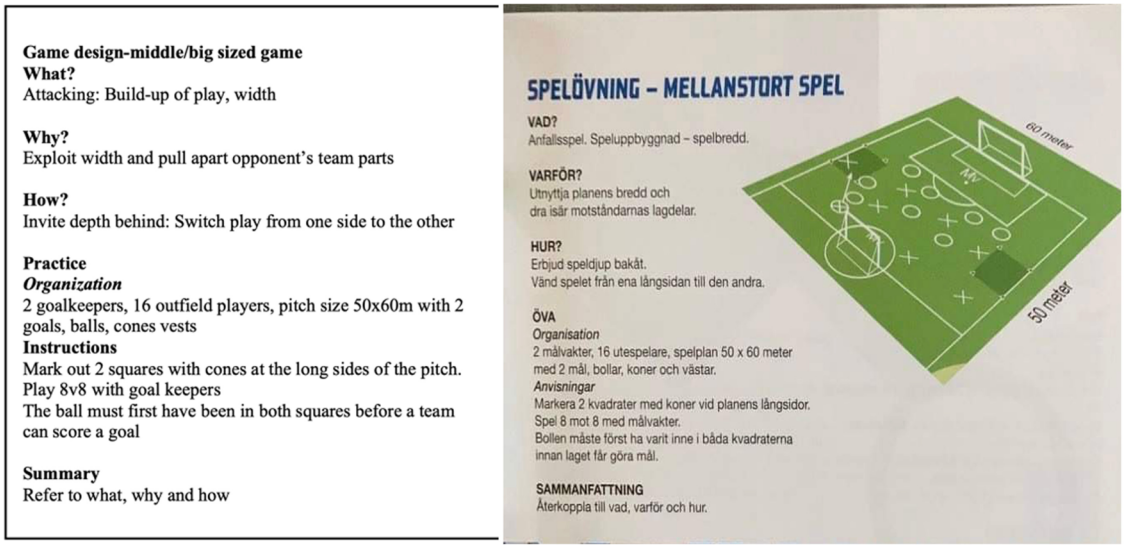
One of the main aims of the new SvFF coach education courses, introduced in 2014, was to support coaches understanding how "Task designs that have the game as the starting point contribute to conditions for increased learning" (72). However, strong socio-cultural influences were arguably contributing to a system inertia. A dissonance between coach educators' socially and culturally constructed beliefs and SvFF's intention to contemporize coach education was evident. Even the more game-based task designs promoted on these new courses were arguably prolonging the shelf life of traditional inherited beliefs about how skill is understood and acquired. Coach C elaborated on his experience attending the UEFA B course in 2018.

> We had an "overlap" themed session. When we were finished, we were asked by the coach educators if we were happy with what we saw. We said relatively happy! Then we got criticized for a lack of successful overlaps. The coach educator assumed that the success of an overlap was when the overlapping player received the ball. The idea of a successful overlap is not about receiving the ball but also about distracting the defenders, pull them out of position and create other opportunities i.e., a gap to pass or dribble through as the defense is moved out of position by the overlap. We were also criticized for not clearly mentioning the theme of the session in the introduction.

Intentions to challenge coach educators' socially and culturally constructed beliefs were not helped by the promotion of artificial task constraints in some task designs to limit unpredictability (control over context). This is captured in the coach educator's assumption in the definitive statement "that the success of an overlap was when the overlapping player received the ball." Another example taken from the same UEFA B course (see **Figure 3**), highlights the use of the rule that the ball must be played from one side of the pitch to the opposite side *before* a team can score a goal. The key problem with this type of "universal" instruction is that, with attackers being invited (by the pre-determined rule) to attack wide areas, defenders may co-adapt their movement behaviours to deal with this rule and change their positions to defend the wide areas at the expense of central areas. Despite best intentions, task designs on coach education courses continued to embody a "control over context" path dependency, limiting player exploration opportunities and contributing to the maintenance of a traditional, hierarchical model, the position of the (controlling) sports pedagogue at the heart of the learning process.

## First probe: AIK base (underpinning practice within a theoretical framework)

Findings from the initial research phase indicated a need to dampen the influence of the "control over context" approaches that were acting as socio-cultural constraints, shaping the



**Game design-middle/big sized game**
**What?**
Attacking: Build-up of play, width

**Why?**
Exploit width and pull apart opponent's team parts

**How?**
Invite depth behind: Switch play from one side to the other

**Practice**
***Organization***
2 goalkeepers, 16 outfield players, pitch size 50x60m with 2 goals, balls, cones vests
**Instructions**
Mark out 2 squares with cones at the long sides of the pitch.
Play 8v8 with goal keepers
The ball must first have been in both squares before a team can score a goal

**Summary**
Refer to what, why and how



FIGURE 3
Svff UEFA B session design (SvFF UEFA B Coach education, p. 43).

intentions (in session design) and attention (during practice and performance) of players and coaches. Considering that macro-level socio-cultural constraints evolve over the years and can be challenging to influence, the DoM focused on the micro-level of on-pitch coaching pedagogy, and in particular practice task designs. To form a coherent foundation for the club's practice design and education programs the "AIK Base" framework (**Figure 4**) was created to encourage the coordination of shared principles and language. Beginning in October 2018 (see **Supplementary Material**), DoM began providing in-house coach education with "on field" support throughout 2019, where the integration of the research to support the development of a player development framework was explored.

Rothwell et al. (11) pointed out that player development pathways could benefit greatly from underpinning their practice within a theoretical framework of the learning process, to mitigate dominating influence of socio-cultural-historical constraints. Grounded in the theoretical framework of ecological dynamics, coaches were encouraged to adopt methodologies and principles of a constraints-led approach (CLA), informing a nonlinear pedagogy in practice (73). The ecological notion of *Football Interactions* was introduced to help shift the narrative away from implementing predetermined "optimal" prescribed actions (e.g., football culture, such as "English top-down model"), towards developing a more adaptive performer. Football Interactions acknowledge that everything that happens on the football pitch is an interaction and these interactions take place in a broader ecology of interactions, beyond the playing area, that shape development within overlapping forms of life. Further, football was defined as a dynamic team sport, in which players routinely flowed between attacking and defensive phases of play. This dynamic offensive and defensive flux, underpinned by the ecological dynamics framework and informed by a modified three-stage learning model, search and exploration; discovery and stabilization; exploitation (see 74), informed "principles of play" at AIK youth football.

## The "sticky" nature of socially and culturally constructed values, beliefs and attitudes

As initial interventions (AIK Base) to probe the system were being implemented, in tandem, the next research cycle (utilizing SIF) sought to capture the evolving sociomaterial environment as it persisted and changed. Due to the inherent, ecological complexity of a form of life, a probe may or may not initiate the change intended, meaning one cannot impose a specific course of action, only probe, sense, and then respond (17), implying that a probe may or may not initiate the change intended. One of the aims with AIK Base was to inform how coaches can design in affordances to support skilled intentionality (coordinate with a broad range of affordances simultaneously). However, path dependencies evident in socio-cultural practices that were anchored to a dominant "coaching" form of life, meant that encultured approaches remained at times challenging to change and were very "sticky". The notion of sticky refers to an ideological inertia, shielding traditionally inherited beliefs about how skill is understood and "acquired" (76).

This "stickiness" was revealed in the "over- constraining" of practice tasks through the application of the game model concept at the club. A game model has been described in the literature as an overarching strategic approach and tactical principles of play, considered of fundamental importance for team organisation to enhance player functionality in specific sub-phases of play (77). The theme "game model" is categorized in the microenvironment, nested between the themes "control over context" and "compliance" (see **Figure 2**), illustrating a value directedness of themes throughout cultural sub- systems e.g., football culture ("English top-down model", "systems of play", "coach -centered pedagogy") and the general sports culture ("professionalisation"), towards limiting unpredictability.

We earlier highlighted a form of game model, where young players were drilled to recall pre-determined passing patterns to be later regurgitated in competitive games [see (2) for more details]. The following section relates to data highlighting how a game model was being implemented in the academy, amplifying player compliance, while aligning with a contribution of practices associated with what was culturally understood as professionalism.

> Meeting with Ragnar (head of development for the boys academy). He showed me some session designs that the coaches have logged in to XPS. In general, the designs looked good but many of the sessions had detailed pre-determined

| Theoretical framework | Ecological dynamics: constraints led approach |
|---|---|
| **Pedagogical concept** | **Nonlinear pedagogy**—e.g. (i) Representative learning design, (ii) repetition without repetition (adaptive movement variability), (iii) manipulation of constraints, and (iv), designing opportunities or affordances for developing relevant information-movement couplings. |
| **Football concept** | **Football Interactions (pass, dribble, off-ball movement)**—refers to how a player coordinates his/her behaviour within the performance landscape in relation to that environment, on the basis of, not only the immediate physical and informational (i.e., situational) demands but also underpinned by socio-historical and cultural factors. |
| **Principles of play** | **In possession:** Search, discover, exploit space and gaps using football interactions. **Recovering the ball:** Close space/gaps, minimise possibilities for opponent's football interactions, win the ball. |

FIGURE 4
The theoretical framework underpinning AIK base (taken from Woods et al., 2020) (75).

coaching points. I wondered "how much insight these presentations of training sessions give into what actually happened in training Are the coaching points a box ticking exercise?" (Field note: 19 January 2020).

Mark: Coaches are clearly spending a lot of time on planning, editing clips and administration work.

Ragnar: What is it we have discussed before? The illusion of professionalism?

Mark: It would be interesting if coaches added in observation and reflections after the session- what happened?

Ragnar: Certification points means lots of administration for the coaches and money [for some it's their salary] is connected to certification. Some of the administration might be of benefit but there is too much.

(Field note: informal conversation, 19 January 2020)

There is a major tendency with coaches to discuss "What" to coach (e.g., tactics, game model), what equipment do we need (footballs, cones). "How" to coach is rarely discussed. I guess that the "How" is harder to administrate! I recall what the Head of academy recently said, "the illusion of professionalism" (Field note: 19 January 2020).

I attend a coach education event organised by Ragnar. The older academy teams (U16, U17 and U19) are presenting their annual plan and how they are implementing a game model in training and in games. Adam, one of the coaches, goes through a few videos of some of the groups most recent games and training.

Adam: We have players filling all the channels [according to the Game Model] when we are in possession, but we still have problems securing control of the ball. We also have problems moving over in defense, we are slow to act.

Bart the U19 head coach presents his training based on the Swedish Football Associations work plan model. I am intrigued to know why he uses this planning model.

Bart: We are not the best at preventing the opponent's build-up of play in this club.

We are in the right position so the players think that this will take care of itself.

(Field note: informal conversation, February 3, 2020)

On a fika break I engage in conversation with Bart

Mark: I see that you are using the SvFF planning model

Bart: Yes, it works well for me

Mark: What do you mean by that?

Bart: Well, it gives structure to the training by having a clear plan to follow. It's about sticking with the plan.

(Field note: informal conversation, February 3, 2020)

The following day I bump into Coach B, now the new u16 coach, on his way out to training. We discuss the previous days presentations and discussions.

Coach B: Players are in the right position [according to the Game Model], so some coaches and players think that everything will take care of itself.

Mark: The coaches seem to emphaise organization a lot, especially in their planning.

Coach B: There is more talk about organization of the players on the pitch, organisation of planning, organisation of administration, than actual football. This is how it has been at the academy for the last few years.

(Field note: informal conversation, February 4, 2020)

During the interviews Coach B had highlighted his concerns on how a form of game model was limiting players but was also establishing a basis for evaluating players. In other words, those players that could conform to a coach-imposed game model had a better chance of surviving the selection and deselection process in the academy

There can still be better solutions outside our game model. This also limits our players and our way of evaluating players. based on the game model. It can absolutely be a part but on the other side limit players.

I was talking about this (with Coach C) and how our game model is quite "fuzzy", where players themselves get to make many of their own decisions from the game from what they discover in the game which I believe will give them more when they are older.

As previous coach interactions with the form of life placed a value on the utilization of deterministic approaches to limit unpredictability, these inherent tendencies shaped how coaches implemented a game model. This was having an over-constraining influence on player-environment interactions. These insights align with a void in the literature identified by Ribeiro and colleagues (77), where there is a lack of understanding of

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how a game model may impact as potent constraints in shaping self-organisation tendencies within sports teams. While players may be taking up the "correct" position in each situation (knowledge about), in accordance with the game model, this does not necessarily imply that they will be able to self-regulate their co-positioning (based on *knowledge of* the performance context) in relation to the continuous local interactions that change at a faster timescale. Foregrounding *knowledge about* the performance context, coaches were prioritizing the operational procedures of coaching, rather than to its actual practice, arguably leading to a *system capture* e.g., doing things the way we have always done them (78).

## Second probe: towards a contemporary player learning in development framework

The second research cycle highlighted the need to dampen tendencies to prioritise knowledge about (emphasizing global to local tendencies in the team) the environment, while amplifying task designs and coach behaviours that promote the development of players knowledge of the environment (emphasizing local to global tendencies between players). Both levels of interaction are intrinsically connected, and their co-existence can lead to successful team performance (77) if global to local tendencies are manifest in "educating intentions" of players. However, through the use **of** a game model, coaches were assuming that they could improve affordances by making them more prominent to players so that they only respond to specifically designed ones. This form of "control over context"/limiting unpredictability, was depriving players of decision making and problem-solving opportunities, minimizing the coupling of perception and action in order to self-regulate behaviour. For example, players being in the right position according to the game model but experiencing problems with their positioning in relation to the fast-changing information. The rigid nature of how a game model was being implemented disregarded the interaction of individual, environmental and task constraints that shape skilled intentions from moment to moment.

Designing tasks which are more *neutral* in terms of outcomes (inviting selection from many possible actions) could better simulate the constraints of the competitive performance environment. In the continued and iterative effort to build on the key ideas of AIK Base, the Contemporary Player Learning in Development Framework [cf. (80)] was proposed to encourage coaches towards more "neutral" task designs, supportive of athlete functionality. A specific feature of this framework is the Foundations for Task Design Model (80), supported by the relational concept of shaping skilled intentions (30), that aims to support the designing of tasks underpinned by neutral affordances (79). The DoM proposed that these ideas could act as a counterweight to find the balance between providing structure or stability (e.g., game models or plans) that constrain players decision making and variation or instability through generating uncertainty and unpredictability representative of competition, in task designs.

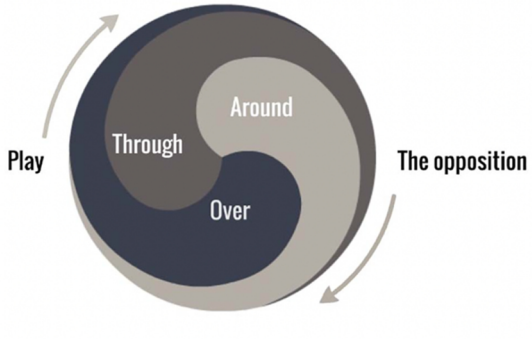


FIGURE 5
An illustration of the constitutive and nested relation of skilled intentions to play through, around and over the opposition in football [from (30)].

Compared to methods relying on verbal instructions of abstract concepts privileging secondhand knowledge about the football environment (76), shaping skilled intentions (**Figure 5**) to guide attention toward dynamic properties of a football environment may be considered as an improvement in the how and why of coaching practice, as it emerges from a more accurate ontology of football and skill learning in development (30). Players display skilled intentionality through skillful responsiveness to multiple nesting and nested affordances simultaneously (30). When designing practice tasks, this approach implies that learning skills should not be looked at as a process of repeating and rehearsing a solution, but more about repeating the process of finding the solution from many that immediately emerge in the neutral affordance landscape. To further encourage this approach, the Foundations for Task Design Model (**Figure 6**), based on the key

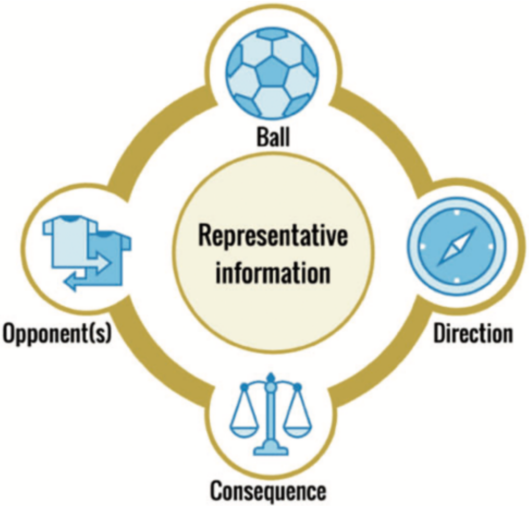


FIGURE 6
Foundations for task design model. Note. Ball-opponent(s)- direction are key aspects of task design that shape learners' intentions and attention. The idea of consequence (e.g., if we lose the ball and do not win it back, the opponents may score), highlights the continuity and co-adaption of attack and defence. Key information in task design is representative of the game (from Sullivan et al., 2021, (80)).

principles of nonlinear pedagogy, was proposed to guide the designs of football specific tasks.

## Concluding remarks

In this paper, we provided an example of how the Learning in Development Research Framework (LDRF) can guide research and action (probes) to capture real-world changes in practice and support the transfer of findings in an applied setting. We illuminated multiple and intertwined unique constraints across interacting systems that transcended disciplinary boundaries and shaped the ecological niche at AIK youth football. For example, forms of life recognisable within player development structures, coaching practice, and behaviours, amplified a value directedness that was rerouting Swedish youth football towards a form of premature professionalism/early elite investment.

The LDRF offers the opportunity for the adoption of an ecological scale of behaviour analysis, with the aim to understand human action in the very contexts (and cultures) that behaviour occurs. The potential it offers practitioners to become more aware of the extent to which unique socio-cultural constraints continuously shapes their work, can support sports organisations to enhance awareness of, and adapt to, these important environmental constraints. In this way, the LDRF offers the potential for the development of a research culture through knowledge mobilization—the act of moving research into the hands of research users. This approach implies that there are no "copy and paste" templates in performance development methodologies. Athlete development frameworks should evolve in interaction with the sociocultural and historical context in which individuals are embedded.

### Strengths and limitations

The results from this study are simply not a generalization across youth football clubs, even in Stockholm. Indeed, socio-cultural and historical constraints that influence player development may even vary from neighboring club to club (mesosystem constraints), due to the unique nature of how different forms of life can interact in a variety of socio-cultural contexts. Indeed, different organizations and clubs will present different opportunities and challenges regarding the implementation of the LDRF, particularly in relation to resources (financial barriers, access to qualified staff) and stakeholder patience (e.g., the growth of knowledge that helps practitioners to understand and identify the socio-cultural constraints, is likely to take time).

We recommend that future research should look for innovative ways to implement and refine the LDRF model across a broad range of sports and sporting contexts at various levels. For example, advances in modern technologies offer great potential towards rethinking and extending how we can carry out such deeply contextualized research as foregrounded by the LDRF. Using tablets, phones or laptops, individuals can become ethnographers in their own community, in their own time. For example, the Wayfinder platform[11] promotes the notion of communities as ethnographers, inviting individuals in a community to contribute stories specific to their own context. Here, members of a community get to determine what is significant and interpret their own material. The potential this form of distributed ethnography offers to consider different types of knowledge and data, may illuminate insights in how to challenge inherent inertias often related to the "stickiness" of dominant socio-cultural-historical constraints. For example, in the context of this study future research could investigate what happens when coach pedagogy aims to promote skilled intentions (skilled intentionality) in football. Can coaches adopt a methodology that prioritises knowledge-of and foregrounds learning in performance, what would this look like in practice, subject to the changing contexts, situations and constraints of the real world in which coaching, learning and performance take place.

The LDRF provides the possibility to enrich the potential for co-creation (researchers and practitioners) of practice, supporting the development of a research culture through knowledge mobilization—the act of moving research into the hands of research users. Aligning with the notion that the LDRF does not prescribe a universal solution, we hope that these suggestions can further guide how researchers, practitioners, clubs and organizations could challenge themselves to adapt strategies to design contemporary athlete development frameworks within their ecosystem.

## 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 Sheffield Hallam University. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

MOS and JV contributed to the conceptualization and background research. MOS and JV developed the research design (data collection, organization, and analysis) and drafted the first version of the paper. JW, JR and KD made critical revisions to the first draft. All authors contributed to the article and approved the submitted version.

[11]https://wayfinders.network/blog/concept-feature-overview/

## 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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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspor.2023.1169531/full#supplementary-material

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# The role of sensous flow and sensing the ground in movement skill experiences—a reflection using the practice of yoga as an example

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This contribution takes a phenomenological approach to explore the sensuous flow and perceived experiences in practicing movement skills, using the practice of yoga as a case study. The article focuses on the role of perception and the anonymous aspect of the body's responses in practicing skills and capabilities to move, with yoga as an example. The author uses a phenomenological framework, highlighting how passivity and sensuous flow is available in the practice of yoga. Edmund Husserl's concepts of passive synthesis and Thomas Fuch & Sabine Koch interpretation of bodily resonance and Kym Maclaren's "letting be" are used as analytic frames to illuminate how movement experiences are dependent on bodily awareness towards the ground, without demanding conscious willpower or focus on force, but listening and sensing with and from the body. The article aims to illuminate the ambiguous character of how movement experienced from a first-person perspective gains importance by understanding oneself, others, and the world as reciprocal and intertwined phenomena.

KEYWORDS

phenomenology, passivity, letting be, yoga, bodily resonance

## Introduction

> *"Embodiment as a paradigm or methodological orientation requires that the body be understood at the existential ground of culture—not as an object that is "good to think", but as a subject that is "necessary to be"* (1).

It has been suggested that the experiences of yoga practitioners, mindfulness practitioners and practitioners of Body-Mind Centering (BMC) of Feldenkrais have somatic foundations (2–4). This means a focus on the "not yet conscious" (5), but ever so sensuously flowing whole bodied experiences where the cells, nervous system, organs, etc., are places where weight, flow, space and so on constitute what these branches of research examine. To elaborate further on the experiences of somatic foundation, I have chosen to build on phenomenology, where the understanding of human movement is based on a bodily experiential and existential foundation (1, 4, 6–12).

The article is written with the aim of theorizing the phenomenon of sensuous flow in movement, with the practice of yoga as an example. The article elucidates how sensuous flow is experienced in a movement practice such as yoga. The structure of this article is an invitation to theorize the intrinsic, dialectical, and ambiguous ways that practising yoga is a way of moving oneself based on experienced of ground, touch and sensuous

flow, which can be defined as somatic modes of attention. My research interest lies in examining how passivity and sensuous flow is practised with the aim of discovering quality, harmony, and rhythm, as well as boundaries and tensions, while moving. This involves examining practices as they are lived and trusting that being in movement has equal value to doing movement. Further that self-knowledge through awareness of the self, body and the world are a basis for movement experiences I have chosen elements from the practice of yoga as a case study. To set the tone of what I want to illuminate in the article, I start by re-telling (13) a situation that illuminates how bodies' uptake of vibrations from the ground directs their movements. I find this situation relevant to use as an entrance to the moving happens from relating to the ground.

> *During the 2004 tsunami, the elephants noticed that the soil and substrate were different than usual, even before the wave reached the shore. They sensed the earth through their feet and saved themselves by moving away from the sea. People, conversely, were keen to see what kind of wave was approaching the shore. The elephants extracted their bodily responses from the world they sensed and "evaluated" the situation far better than the humans, who let their concern about seeing what was happening have an impact on their actions.*

This example provides insight into the non-conceptual, yet ever so clear, understanding of the elephants' embodied connection to their surrounding environment. The elephants' actions showed how they perceived and responded to the vibrations in the earth through their feet and their whole bodies. The elephants "listening" to the processes of the "inner" body in relation to their environment and and "asking" the earth if they were safe or in danger. According to Fuchs and Koch (9), the example shows what animals do when they, through their bodily experience, examine whether a tree is climbable or whether water is drinkable, for example. So, the question is: why were the people keen to see the wave, and why did they prioritize their visual senses over kinesthetic listening, which means to listen through the skin and feel the contact with the ground, and linking this to their relationship with the earth and the ground through their feet? There can be many explanations, which I do not follow up here. What I draw attention to is the the principle that human beings embody the same relationship with the earth as animals, but as mentioned by Berg Eriksen (14), senses like vision and listening team up with intellect to create a response, while kinesthetic feeling and sensing team up with the body to do so[1]. However, as Berg Eriksen points out, a hierarchy exists between the senses, where vision affects distance and judgment and invites the subject to obtain a third person and objective point of view—while the more bodily senses such as touch, smell and taste take a first-person, subjective, and intimate point of view that requires proximity. Phenomenologically speaking, Fuchs (15 p. 222) wrote:

> "We feel something 'in the air', or we sense an interpersonal 'climate', for example, a serene, a solemn, or a threatening atmosphere. Feelings befall us; they emerge from situations, persons, and objects which have their expressive qualities and which attract or repel us. This emotional space is essentially felt through the medium of the body which widens, tightens, weakens, trembles, shakes, etc. in correspondence to the feelings and atmospheres that we experience"

This means that something that might be felt as if it were "in the air" is assumed to be available as a noticeable condition in the body and that this should not be dismissed, but rather pursued. Accordingly, it follows that one's relationship to oneself, others and the world is felt and anchored in a personal relationship that in social situations, before a word is even said, we experience each other through being spoken to or ignored. Unpacking experiences without words shows us exactly how experiencing sensuous feelings take place in shared spaces and that the self, world and others belong together and "reciprocally illuminate one another and can only be understood in their interconnection" (16). In this interconnection, there are moments of responsivity which are "passive". However, "passive" does not mean static or inactive, rather it indicates the synthetic work done by the consciousness that *goes unnoticed* while it is engaged in direct (i.e., active) experiences, which Husserl elaborated on in his paper on passive and active synthesis (17). For Merleau-Ponty, the anonymous refers to a level in perception which concerns the depth of perceptual presence (18). When the elephants sensed a vibration in the earth, they illuminated the reciprocity between sensing the earth through touching the ground and sensing the feet and body weight contact with the earth, e.g., moving and being moved. As pointed to by Bainbridge Cohen (2), yielding to the ground also creates access to moving in and through space, both to moving forward as the elephants did and also to the sensual depth of the experience and situation. It is significant and relevant to elaborate on being in *the present movement* in movement, while also being attentive to space, including to human beings moving. Such an elaboration also functions to illuminate the question that remains: why were people keen to see the wave? What kind of position did people take when they seem to prioritize watching the wave and perceiving it as something exciting through their vision? As de Jaegher (19) writes, "Characterizing knowing as a relationship of *letting be,* provides a nuanced way to deal with the tensions between the knower's being and the being of the known, as they meet in the process of knowing-and-being-known". But what does it mean to deal with oneself as a knower of movement and what is being known? (20–23) To follow up that question, I will position the perspective of the article more clearly in phenomenology.

[1]This can be viewed as a dualistic position, and I am not sure that such a split is generally valid, but it illustrates the situation with the elephants.

## Bodily experiences from a phenomenological perspective

Phenomenology is a European philosophical tradition that has had significant worldwide influence on thinking, research, architecture, art, culture, and other branches of the humanities (24). While there is no single answer to the question of what phenomenology is, it is generally agreed that Edmund Husserl (1859–1938) is the "father" of phenomenology. Husserl radicalized the theory of knowledge of his time and aimed to show that the building of knowledge based on a separation between the world and the knowing subject was rooted in an erroneous view of understanding. He wanted to broaden insight into human experience in the *lifeworld* in which people live together with one another and engage in communicative relations (24, 25). The lifeworld is a perspective that forms an existential precondition for engaging in different social worlds in which human needs and intentions are related to and in transition from one generation to another. It enables intersubjective communities and shared meanings as well as interpersonal relations and embodied affects to circulate between humans (26). Conducting research from a lifeworld perspective means understanding human beings as being inseparable in a shared world (24). However, living in a shared world also means that humans tend to be largely unaware of their own bodily movements, own language, and habits in everyday life (6). I take this as an opportunity to unfold movement experiences that we can be aware of, and benefit from. The philosopher Maurice Merleau-Ponty (1908–1961), known as the "philosopher of the body," developed the concept of the *lived body*, in contrast to an abstract and mechanical body. He wrote:

> We have relearned to feel our body: we have found underneath the objective and detached knowledge of the body that the other knowledge which we have of it in virtue of its always being with us and of the fact that we are our body. In the same way, we shall need to reawaken our experience of the world as it appears to us insofar as we are in the world through the body, and insofar as we perceive the world with our body (11).

By re-establishing the contact between the body and the world, Merleau-Ponty viewed the body as ambiguous and unfolded in a double sense (e.g., subject and object, seeing and seen, touching, and touched, sensible and sensed). In his unfinished work *Le Visible et l'invisible* (1968), he conceptualized the body as the *flesh of the world*: as both expressive and anonymous. The subject herself cannot, in certain aspects, know herself. She can say "I want to go for a walk" but not "I want my heart to beat." Thus, the body is both present for a person and distant and alien (27), as there are phenomena in the body that live "their own life" (e.g., heartbeat or breathing). This means that when phenomenological researchers pay attention to the passivity of and sensuous flow in the body, they contribute, according to Merleau-Ponty (11), to create insight into experience of shared situations and how movement comes from- and are performed in relation to the ground, others and in and from one's own body.

Back to the the elephants, who moved themselves to safety, while human beings were curious to see and gaze at the wave. Touching the ground is an immediate sensation felt in the body. The gaze creates distance and judgment and the somatic modes of attention (1, 28). The wave probably appeared to the people as "important" or, in a strange way, "attractive" (9). This brings us to the understanding of bodily resonances underlying micro-sensations; feelings of warmth or coldness, tickling or shivering, pain, tension or relaxation, constriction, or expansion, sinking, tumbling, or lifting, etc. They correspond, on the one hand, to autonomic nervous activity (e.g., raised heartbeat, accelerated breathing, sweating, trembling, visceral reactions), and to various muscular activations, bodily postures, movements, and related kinesthetic feelings (e.g., clenching one's fist or one's jaws, moving backwards or forwards, bending over or straightening oneself, etc.) on the other. Without these sensations or others as part of our experiential knowledge, the world lacks meaning, and as pointed to by Fuchs & Koch, when people are affected by affordances of a situation, it triggers a specific bodily resonance ("affection") which in turn influences the emotional perception and evaluation of the situation and implies a corresponding readiness to act and speak, through their energy, tone, and manner (2). From a phenomenological perspective, bodily and affective resonance and interaction with others are what allow people to understand each other.

In summary, the subjectivity and intersubjectivity in the understanding of movement experience the elephants' sensuous, and bodily response to- and the relationship with the earth that this gave them, helped them to take the decision to move in the right direction, away from danger. Far from being barriers to making correct decisions, bodily sensations relate to the knowing body and can help us to make decisions in all sorts of situations. Relying on sensation in knowledge creation is also advocated for by Hanne de Jaehger and Kym Maclaren. By including Maclaren's concept of "letting be" with regard to practicing (movement), it is possible to further elaborate on this idea in order to illustrate that the way in which the moving subject approaches and orients themselves from their experiences is where the qualities of the movement are discovered and differentiated (28). Edmund Husserl's concepts of passive synthesis and hyletic flow (19), Kym MacLarens concept of "letting be" are used as analytic frames to illuminate how movement acquisition is dependent on silence and awareness, without focus on force, but of "letting be". From a phenomenological perspective this allows for the exploration of the body's unique capacities to interact with the ground, space and others (human and other species) as the environments they inhabit and move and create movements within [cf (30)].

## Creation of method and material through practicing yoga

As already stated, I use examples from yoga practice to help to theorize the somatic ground, bodily resonances, and value of

"letting be" as part of movement acquisition that I am interested in. These examples are created from autoethnography, which is a collective term for ways to develop knowledge by creating a material by combining personal reflections in combination with reflections on cultural and institutional conditions (31, 32). My examples have been created by narrating experiences from practising yoga. In this article, I have chosen to highlight experiences from three situations. I have asked myself what some self-perceived bodily conditions in yoga practice can provide knowledge about beyond what is known and discovered about yoga practice and experience of sensuous flow. My use of this example is not intended to be interpreted as empirical fact or as experiences that are unique to me or others (6, 8, 33), but rather as actual and possible examples of "the same kind of phenomenon" (6). In line with Behnke, my interest "is eidetic, not empirical, and the specific examples chosen are merely meant as clues toward structures that could equally well be illustrated by different examples" (p. 185). It mean that when I have analyse the experiences from yoga, I have aimed at pointing to a more common humans experience of moving, that indicate how sensuous flow and passivity in receiving—and relating to the ground are shared phenomenon in experiencing movement.

## The yogi's experience of moving themselves into passivity and stillness

Yoga traditions are numerous and are of great interest to philosophers, researchers, and practitioners world-wide. Here, I touch on some situations that many practitioners have in common, a position called *shavasana*, a Sanskrit name derived from two words: *sava* meaning "corpse" and *asana* meaning "posture." Traditionally, the *corpse* pose is an asana performed at the end of a yoga session, in which practitioners lie flat on their backs with their heels spread as wide as the yoga mat and their arms a few inches away from their body, palms facing upwards. *Shavasana* is considered a practice where the yogi gives their body to the ground and relaxes by being attentive towards breath and weight and allowing kinesthetic and somatic modes of attention that arise from the unity of the body and the spatiotemporal field. When engaging in *shavasana,* the traditional idea is that intentionality is directed towards preparing the body for death. This is a text that I, as a yoga practitioner, wrote after a yoga class:

> *I am lying on my back, flat on the floor. The room is warm, and I feel the bright light even though my eyes are closed. The teacher tells us that this is our reward after the challenging session and all we have to do is relax and let our bodies sink into the floor. The floor is trusting and safe. I feel my body tensing up in the shoulders—why? I feel the floor touching my body and my body touching the floor. In the beginning, the two are different, then they merge, and I am one with the floor and the space, no borders but indulging in deep relaxation. The outbreath and inbreath, just follow and are at one with my breath. Suddenly, I hear the teacher's voice, it seems to come from far away. "Take a deep breath in, a deep breath out, slowly in your own time, come back to your awareness of your body. When you are ready, take a deep stretch and roll over to your right side. Take your time to come up to a seated position".*[4]

The experience in *shavasana* felt like being carried away from the actual space. The teacher's voice combined with listening to what was happening in my own body, the movement experience and the passive receptivity contrasted strongly with the movement experiences that preceded *shavasana* in the yoga session. Being in *shavasana* creates opportunities for someone to explore the subtle layers of being, the invisible levels, where passive synthesis and the kinesthetic mode of attention [cf (34)], accordingly, move the body into stillness. In this stillness, a type of transformation occurs, and a feeling of being one with one's circumstances arises. The yogi gives themselves over to the (spiritual) world and transforms their world, like the painter transforms the world with their painting. During the transformative phase, the yogi's attention descends to subconscious, unconscious levels which opens the way for Husserl's passive synthesis as a particularly important dimension of experience. *Shavasana* brings the yogi into subtle modes or regions of experience and cultivates a sensibility appropriate to the phenomenon of relaxation. In *shavasana*, the voluminous body often no longer feels its borders with space but is instead one with its circumstances. Nothing is actively moving, and the silence of deep relaxation floods the body. When the teacher in this situation asked the yogis to "bring awareness back to the body", they built on their knowledge of the phenomenon of long-time practice within the tradition, and they were teaching from an experience that echoes the "understanding in [their] bones" (35). The visual process of *seeing* is no longer given a prominent position. However, *sensing* and *feeling* are the bodily functions that embrace the current moment and turn the moment into a healing one, where the sensory intake and bodily awareness towards oneself, others and the world and the other plays a significant role.

## The yogi's experience of being suspended between ground and space

> *I am standing on my feet, gazing forward into space. The room is warm, and the ground feels, down, deep down, as if roots are growing. I clearly feel my feet touching the ground, I perceive the ground. I feel the surface of the ground and my feet touching. Above me is the "air" and I reach up by floating my arms above my head, touching each other—coming together. Suspended in space, grounded. As I breathe out, I let my arm follow the front of my spine, trying to meet the ground. The*

[4]This example is also used in (8).

> *teacher tells me to enjoy the forward bend. For a moment, the tensile forces that held me up melt into the ground and give the weight to the ground, still not collapsing. My hands and feet together—for a moment both seeking support from the ground, have the same function: feet as hands, hands as feet.*

The base of the movement in the part of the body that touches the ground is the anchor of one's support and is an expression of the ontological understanding of the bodily movement as *a being in the world*. The double sensation of touching and feeling the gravity that I am yielding to but also pushing against in a yield and push pattern, which creates a productive tension and suspension of energy to move with, to manifest and involve relationships, and to create experiences that fluctuate in terms of the movement, meaning, and environment and ground. Such experiences are not measurable; they are part of the existential condition of living as a bodily subject in a double dialectic as both the one who touches and the one who is touched (11). The moving subject is the one who is the self-moved mover, that rests upon a positive appeal to the experienced unity of the freedom in the spatiotemporal field, and which, according to Todes (36), is a field that is produced by the way the body's specific structure both constrains and enables one's movement skills. Fuchs (10) claims that, through bodily resonance, we notice and gain an intuitive understanding of the feelings of others, and that this arises in our bodily engagement with them and the world (I refer to the elephants that noticed a new vibration in the soil). This is a perspective in which the mover clearly notices bodily somatic sensations, from which the body is mobilized in wonder and explorations of moving and being moved, like how Fuchs and Koch (9), describe what animals do when they examine whether a tree is climbable or whether water is drinkable, the mover asks the movement: can I move here, can I connect there, how do I create space and move in space?

## The primordial and non-conceptual understanding in silence

The primordial and non-conceptual understanding that yogis' experience in *shavasana* is clear to them when they compare the different movement experiences during practice. The different objects for reflection are intertwined in the relationship between being and having a body, as shown in Merleau-Ponty's example of the two hands touching. Merleau-Ponty gives credit to the primordial and silent language of the body. "Les voix du silence" refers to those who do not speak about the world, but instead let the world come to light and discover the experiences that hide behind discursive language (e.g., 37). I compare the way the painter transforms their surroundings in their painting with how *shavasana* is an art of relaxation that subtly shifts the parameters of the yogi's world when they release their body to the ground. However, doing nothing, receiving the ground, and giving up visible movement activity can be challenging. Finding relaxation in *shavasana* is also an achievement, a way of being in the "here-ness" that Husserl called the ground zero of orientation (7). At the same time, entering *shavasana* means experiencing a place where the perceptual field is simultaneously limited by closed eyes yet expanded by an open imagination and a floating feeling where the body and the world are in union.

## "Letting be"

According to Maclaren (38), it can be challenging at first glance, particularly in relation to teaching, to take in and accept the words "letting the other be" as they can lead to thoughts about encouraging a "passivating" attitude towards others, or, as one might express it in everyday speech, to allowing others to go their own way. Maclaren's idea of "letting the other be", also relates to "letting oneself be", and, as previously stated, expresses a fundamental way of being in the world, both subjectively and intersubjectively. It shows that in praticing yoga in an intersubjective environment yogies are exposed to each other. "Letting the other be" also means feeling *oneself* as present and being "here" and feeling the "me-ness" of being here. When it comes to the bodily experience, "letting be" relates to body weight, volume, structure, senses, thoughts, and feelings of the body as they are from moment to moment and experiencing "releasing our body weight" towards the ground and registering what this does to our openness and presence in dialogue with others (40).

Giving space to "letting be" becomes meaningful when the yogies understands themselves and others by engaging with and taking each other in through the body. Thus, before a word is said, human beings know quite a bit about the mood of a room and the quality of the contact with others in it. The fact that human beings can *notice* and *sense* others through the body is due to our bodies belonging to a common world (41). Maclaren (29), also writes that the person who lets others be is aware that for many people it means a struggle with one's own preconceptions of the Other. "Letting be" requires me to find my own free space within myself and my relationship with the Other. It means being able to suspend one's own habitual thinking and understand that movement experience occurs between and within human relationships in the world.

## Embodied learning through grounding the weight

No movement, whether it be of an elephant or a person, can be learned without relation to the ground. The body parts that touch the ground processing the bodily weight, that further are driving forces for action and movement; without the relation and releasing the weight to the ground, a movement will die or break. The mover must feel and sense the ground and skin before it becomes a "motor" action, whether it is snow under skis, rain pelting down on the body, the other's nice smile, the squealing of tram tracks, heat in the head, or a loud whistle. Allowing time *to be* is a theme explored in practices like Feldenkrais, Body-Mind Centering, Dance Improvisation, in addition to yoga. Hanne de Jaegher comments on this as follows: "Characterizing knowing as a relationship of *letting be* provides a nuanced way to deal with the tensions between the knower's being and the being of the known, as they meet in the process of knowing-and-being-known" (de

Jaegher, 2019, p 1). Including the idea of "letting be" provides a perspective for exploring and reflecting upon what considering this phrase might provide in using the sensations from one's own body to help to avoid objectifying and quantifying one's movements only as products. By opening the spatiotemporal field for shared knowledge and dialog, acquisition of movement happens "by itself". Considering the non-conceptual bodily sensations that the elephants used to escape the tsunami, human beings may practice listening to the bodily resonances and be guided in the same way as the elephants understood that they had to escape and move away from danger. The mover might, like the animal that wonders whether the tree is climbable, ask themselves if they are available for contact, with the movements, others, space, or environment. Bodily resonances will, if given attention, function as a driving force for direction and dynamic movements. Bodily resonances and affective relationships with the ground show humans as emotional bodily beings that live together with other people and circumstances in the world (36), and that the practitioner achieves embodied self-knowledge (12). One argument for embodied self-knowledge in movement acquisition practices is concentrated upon "re-achieving a direct and primitive contact with the world and endowing that contact with philosophical status. It is in the search for a philosophy which shall be a 'rigorous science', but it also offers an account of space, time, and the world as we 'live' them" (11). We can take inspiration from Merleau-Ponty's approach to acknowledge that a person's own subjective bodily experiences can count as knowledge. A subjective perspective means that the living and lived body, from a first-person point of view, is not a perspective that could be observed from other perspectives: "It is our very manner or way of being in the world and, as such, it allows us to adopt perspectives in the world. Thus, we "are" our bodies in a fundamental sense" (41). I take this as an argument to include bodily self-knowledge, which means discussing the role of experiential knowledge, subjective knowledge, embodied knowledge, self-esteem, and self-awareness in movement practice and regard those phenomena as a precondition for such knowledge in a broad sense.

## Summary—the potential for experiencing moving and being moved

I have provided examples in in favor of including sensitizing oneself to the practice of "letting be" in movement experience and include passivity, sensuous flow and the not-yet known as potentials for understanding one's own movement experiences and orientation. By highlighting emotions as driving forces for movement and action, I have tried to give space for a phenomenological, existential, and relational ground for practicing movement with inspiration from the elephants and situations from yoga practice. To learn about oneself by noticing the qualities of one's own body, spontaneity, or lack thereof, experiencing of what is tense, loose, available, or stuck is to discover and gain insight into the way one moves and are moved. The double sensation of moving and being moved, touching, and being touched give a clear insight into the orientation towards how movement is experienced in yoga practice. By highlighting that human bodily emotion and sensation are a basic approach to movement and a basis for knowledge, the concepts of bodily resonances and "letting be" lay the theoretical groundwork for using interactive processes that occur in the bodily resonances, spaces, and awareness practiced by the moving subject when they use little effort and increased sensibility. Taking such perspectives into moving allows the mover to understand movement as a process that underlies any product-oriented perspective on movement. The perspective in this article supports exploration of movement and includes the "whole body as being and being moved" (9). It means letting oneself be moved by the movement in reciprocity, to act and direct one's movement to fulfill a purpose or desire. I want to make angels in the snow, lay down and rest, or take my dog for a walk. The mover's responses to oneself, others, and the world and environment are keys to understanding the role of the sensuous and passive aspects of moving and being in the world as embodied subjects, and how phenomena of "letting be" adds quality to movement experience that might also be transferred to theorizing movement experience and acquisition within other branches of research within sport sciences.

## Data availability statement

The datasets presented in this article are not readily available because: the autoethnographic materials used in this article have the function of examples for highlighting the author's understanding of the movement experiences.

## Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

## Conflict of interest

The author declares 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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# The (cognitive) future of motor control and learning

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An ongoing debate exists regarding the compatibility of dynamic systems theory (DST) and symbol processing accounts (SPA), where SPA assume abstract representations and processing. Another aspect under discussion is if either one appropriately describes and explains motor control and the modification of motor skills. Both frameworks have their strengths and weaknesses. DST provides mechanistic explanations and takes system complexity and the environment into account without reference to mental entities. System behaviour is described mathematically and considered deterministic. In contrast, SPA propose that abstract content, that is, mental representations of the (own) body, and task requirements are critically important for movement control. It is argued that neither approach nor an (unaccomplished) unification of these frameworks can achieve a comprehensive understanding of motor control and learning. In this perspective article, it is argued that further effective sources of motor learning, such as emotional support and motivational guidance, have the potential to improve and preserve motor skills indirectly and should, thus, be recognised. Qualitative approaches focussing on understanding the athlete and the situation might be appropriate for applied work.

KEYWORDS

motor learning, skills, motivation, emotion, representation, coaching

## 1. Introduction

This perspective article calls for terminological precision when referring to theoretical foundations and advocates a broader perspective on motor control and learning. Learning refers to the modification of our action repertoire. More specifically, motor (or skill) learning refers to the long-term process of acquiring and improving (actually changing) goal-oriented movements, specifically muscle activation patterns [cf. (1–3)]. In contrast, motor adaptation can be differentiated from skill learning in that it refers to shorter responses during learning [cf. (4), including a discussion of the role of errors, reinforcement, and reward]. Skill learning can proceed implicitly or explicitly. Thus, explicit (including verbal) input from the environment or other persons, such as observation, instruction, or feedback, can foster motor learning.

A comprehensive understanding of skill learning is essential because motor skills are required throughout the lifetime and in almost all aspects of daily life. Strengthening skill learning is necessary to achieve high performance levels and reduce sedentary behaviours and associated health-related costs for societies. Relatedly, physical activity and motor abilities have declined significantly in (mainly Western) societies in recent decades [e.g., (5–8)], with some recent stagnation (9, 10). A comprehensive perspective is needed not only to maximise peak (sport) performance but also to optimally support the acquisition, improvement (e.g., in physical education), and rehabilitation after impairment of basic motor skills.

Understanding human skill learning is not trivial because of the complexity of the movement system, incl. all bones, joints, and muscles [for related discussions such as the motor–action controversy, see (11)]. Moreover, there are various other influential factors such as external stimuli (physical to social), biological energy supplies, nervous control structures, and psychological states [cf. (12)]. All these factors should be considered to provide optimal support for skill learning. A comprehensive scientific theory may reduce potential influences to the basic effective factors, and such a theory needs to explain a wide range of actions. Not limited to sports, we need to understand how humans perform actions with the highest precision demands (e.g., dart throwing and clockmaking), maximum force (e.g., weightlifting and construction work), high speed (e.g., sprinting and running), or even a combination thereof (e.g., pole vaulting and forging). Given the complexity of human movement control (incl. aims), a comprehensive theoretical basis is required for optimal support.

## 2. Theoretical approaches

Two contrasting classes of scientific approaches, namely, dynamic systems theory (DST) and symbol processing accounts (SPA), will be discussed to understand human movement control and learning. The underlying foundations appear incompatible, and missing factors will be considered, contributing to the difficulty of reaching a comprehensive, unified account.

### 2.1. Dynamic systems theory

To understand (i.e., describe) the overall behavioural variability of highly complex systems (e.g., humans), DST considers all the system components (e.g., body parts, muscles, and organs) and environmental influences. Any system behaviour is construed as a pattern (of change or action), and these patterns can either be stable over a range of relevant variables or change within a small (critical) range of system variables. The interplay of variables and, thus, the system behaviour are described in a set of mathematical formulas. The mathematical equations of DST originate in physics [cf. (13)] but have been applied explicitly to "both animate and inanimate systems" (14, p. 3) [see also (15)]. Movement coordination and cyclic movements have often been focussed on. According to DST, motor control is inherently less demanding (actually, it assumes no control entity) because the properties of the body parts (e.g., length, masses, and tissue stiffness) contribute to movement control [as system subcomponents, e.g., damping of the movement end; cf. (16)].

The main objective is to describe the changes in a system *over time*, which is an important aspect of DST. The term "dynamic" refers specifically to the dependency of variables on their values at an earlier point in time. Technically speaking, the previous system state at time $x_{n-1}$ determines the system state at time $x_n$ (variables may, of course, also be influenced by other variables). Such mathematically described developments over time indicate causal relationships. That is, the changes in system states are *deterministic* (14, p. 19) [cf. (17) for an application to psychology; (18), as cited in (19)]. Deterministic processes are interesting because they have the potential to (fully) explain phenomena, although such explanations require measuring (all) relevant variables to go beyond a mere description (i.e., to provide evidence for the explanation).

Furthermore, the deterministic nature of DST makes any higher-order control structure unnecessary (14, pp. 26). The changes in a system behaviour (pattern) result mechanistically from the current system state and the previous state. This is referred to as *self-organisation* and a central property of DST (14, p. 8, ch. 2). Consequently, the changes in the system state over time (e.g., the unfolding of movements) are *fully* determined by current and previous variable values. No mental state, symbolic representation, or processing is required for system control [e.g., for movement execution; cf. (20)].

Although rigorous regarding the target phenomenon (deterministic with mathematical precision), DST is interesting because it can describe a wide range of movements with a single set of equations. The system behaviour is described as stable and flexible (14, p. 20). For example, walking (a cyclic movement pattern) is more or less constant (stable) across a speed range. If the speed increases to a certain point, then the movement pattern changes drastically (e.g., into running) within a narrow speed range (flexible). Similarly, for running, the movement pattern is stable across a wider speed range. Furthermore, such models do not contain logical (or intellectual) relations, for example, in the sense of *if* (the speed is greater than $X$) *then* (switch to running)—*rules*.

Based on the DST framework, multiple variable learning episodes (experience) should generalise and improve specific skills (21). These ideas have been *conceptually* applied to practise, in that athletes are given multiple different movements as instructions to improve and maximise their motor skills [e.g., (22–24)]. Proponents *assume* that stable movement patterns (which are optimal for a given situation) emerge due to widely varied experiences.

### 2.2. Symbol processing accounts

In contrast, symbol processing accounts assume that human actions, that is, body movements, are controlled by a motor plan or instruction (25). These commands to move are abstract entities (symbols or internal representations) with specific meanings. The motor commands (and their sequence) result solely from computations (information processing) on smaller units, such as movement parts, intentions, and other external information such as distance to goal. The origin of SPA dates back to the *cognitive turn* of the 1960s, when the "mind and brain as computer" metaphor developed and *plans* as hierarchical descriptions (from strategies to muscle commands) became central to understanding behaviour (26). Plans were computed as sets of instructions for the intended behaviour. These computations can be compared metaphorically to sentence construction [from words and grammar rules (27), but see (28)]. Hence, SPA can be said to be language-like.

In addition to mechanistic motor control such as reflexes, SPA extends the mode of movement control to voluntary actions, which do not depend on any stimulus. This "openness" to mental states (e.g., goals and reflections) is one strength of SPA as it implies a non-deterministic perspective on human actions [i.e., it is not physically causally closed; e.g., (29)]. The openness to mental states provides a theoretical basis for applied work, for example, mental training (30–32). In addition, these accounts can incorporate *reasoned* decisions in computations (e.g., logical thinking or conditional choices); that is, an argument can be incorporated, which appears natural given that many of our actions are perceived as reasoned decisions. Another advantage is that researchers can perform computations (static, statistical models) based on empirical data.

A fundamental issue with SPA is that it remains unknown how representations "emerge" from physiological activity [cf. 33, 34]. In a similar vein, it remains unclear how a representing neuronal signal can *stand for* something else, namely, the entity it refers to, and how mental states (e.g., intentions, goals, arguments, and decisions) influence the biological level, that is, the functions of the nervous system. SPA is described to be disembodied [processing is understood in terms of symbols or propositions, and motor control parameters are largely ignored; cf. (35–37)].

The so-called degree-of-freedom problem is another illustrative limitation of SPA [first described by (38); (39, 40) for discussion]. Given a specific movement goal, for example, reaching an endpoint (e.g., a cup of tea), there are many trajectories to perform the movement. Yet, such a movement does not pose any difficulty in real life. Nevertheless, evaluating all possible trajectories to determine the optimal one seems impossible. The fact that even computers cannot achieve such calculations in real time (as fast as humans or animals perform such actions) indicates that the approach is conceptually inadequate; hence, other research strategies are pursued [e.g., (41)].

# 3. Discussion

The SPA and DST frameworks can be construed as diametrically opposing endpoints of a spectrum of theories, both having advantages and disadvantages. Unfortunately, they cannot be "merged" without losing the advantages; these frameworks are incommensurable paradigms (42, 43). In brief, DST is deterministic and does not need "expert supervision" [i.e., a dedicated control structure, cf. (14, pp. 8, 26; 20)]. In addition, DST makes mathematical predictions for all time points, and for a prediction, (initial) variables need to be known with infinite precision ("exact"). Consequently, DST must be seen as descriptive in nature and not explanatory. DST cannot be used for a specific case because not all variables can be measured nor measured exactly.

In contrast, SPA are open to mental influences and cannot be deterministic (in the sense of physical causation). The SPA *are* applicable to empirical data, that is, to specific cases, mostly as statistical associations (rather than full deterministic relations). Furthermore, SPA are easier to develop, for example, in light of new data or insights; it is easier to edit, add, or remove variables. Because the advantages of one framework are almost the disadvantages of the other (e.g., a theory or framework can either be deterministic or not), any attempt to *somehow* merge these frameworks would erase the respective advantages.

## 3.1. Critique

An enormous number of theories (see also below) have been developed between these diametrically opposing endpoints of a spectrum of theories. The present work aims at a principled call for theoretical clarity and precision of terminology. Although some examples will be mentioned, it does not represent a critique of individual, specific research.

Based on ecological psychology (44) and connecting it to DST, the terminology partly changed to "ecological dynamics" [e.g., (45–47)]. The inclusion of "dynamics" may create the impression that the theory in question is founded in DST with its deterministic explanation of system behaviour but the terms are used inconsistently. For example, Rudd et al. (48) considered the domains of environment, task, and individual and discussed the learning aspects *within* the perspective of the coach or teacher. The complexity of the learning process is referred to as "non-linear pedagogy" [ibid, pp. 4; cf. also (49)]. The use and combination of such terms, for example, together with "constraints" and "ecological dynamics," may propel the idea that the theory is be grounded in DST. Wood et al. (50) considered the coach as the third domain of interest (next to environment and task). Others focused on the athlete–environment interaction within an "ecologically situated perspective" ((51), p. 18). Furthermore, the athlete–environment interaction should embed emotions in the interplay of cognitions, actions, and perceptions (52). The quoted studies illustrated the imprecise combination of terms, which may lead to individual interpretations and, potentially, misunderstandings. There is no doubt that in the above-quoted examples, the separate concepts (e.g., emotion, task, coach, and athlete) are important and exert critical influences in skill learning, but the concepts need to be differentiated, and terms should be used consistently.

Regarding psychology, Gelfand and Engelhart (53; cf. also 17, 19) pointed out a potential confusion of dynamic systems with static models. Critically, dynamic models state that the system state depends on the same or other variables at an earlier point in time. This time dependency must not be confused with "non-linearity" (53). By analogy, DST may describe similar patterns of system behaviour as seen in motor skill improvements (15), but the need to prove DST as the explanation (which requires identification of *all* relevant variables and *exact* measurements) cannot be satisfied [cf. (53, 54)].

## 3.2. Other frameworks

Many theories recognised that the body (next to a symbol-manipulating device) and the environment must be considered to understand human behaviour. Gibson (44) emphasised the role of environmental factors, calling the framework *ecological*

*psychology*. Accordingly, the environment interacts with the athlete [e.g., (56, 57)] and must be considered.

Factors related to the body have been discussed in the *embodiment* framework [(57) for review]. Here, it is emphasised that cognition is *not* independent of the body (and the situation). That is, cognition is seen "to serve the needs of a body interacting with a real-world situation" (ibid., p. 635). Crucially, the connection between the mind and body is bi-directional. Sensorimotor representations are seen as the basis for mental simulation, which is at the core of mental training.

Similarly, the ideomotor framework proposes bi-directional links between perception and action [cf. (58, 59)]. A related theory is the perceptual–cognitive approach to voluntary movement coordination (60, 61). Interesting evidence and arguments are provided for the *leading* role of (rhythm) perception in executing movements. Although much work is devoted to cyclic and often bimanual actions, this theory has also been applied to skilled movements such as the tennis serve (62) and other sports (32). Mechsner (60, 61) suggests the existence of movement representations, highlighting that they are sparsely coded (no full body parameterisation) and that perception (including re-afferent body signals) has a leading role in motor control.

The environment, as well as the task, has an impact on our actions and skill learning (25, 63) [for an action-centred perspective, see (64, 65)]. The task represents the action goal, which is allocated on the psychological (symbolic) level. Importantly, the action is also embedded in the social situation. These insights have been incorporated conceptually within the idea of systems theory [e.g., (20, 66)] without a mathematical formulation as in DST. This is reasonable because systems theory emphasises synergies among (interacting) components, and from lower levels, novel functional properties can emerge at higher levels (e.g., mental states or social phenomena such as team cohesion). Since all factors (environment, person, and task) are considered in such a perspective, it might be conceived of as comprehensive and at least conceptually holistic.

### 3.3. Considering a wider perspective

Given the frameworks discussed above, one may consider further factors that impact motor performance. In addition to coaches providing direct input to athletes to support skill improvements (i.e., movement-specific instruction and feedback), one should consider factors that impact motor performance indirectly. Such indirect (i.e., movement-unspecific) influences may range from team building [e.g., (67)] and leadership [e.g., (68)] to coaching [mentoring; e.g., (69)] and counselling [career development; e.g., (70, 71)]. An indirect input can stabilise performance, and tools of mental control can address emotion regulation (i.e., coping) and motivational (e.g., goal setting and routine development) and volitional aspects [e.g., self-talk and imagery; cf. (32, 72)].

To understand (psychologically) the needs of an athlete, a qualitative method, that is, a phenomenological or hermeneutic approach, would be adequate [e.g., (73); see (74, 75) for reviews]. To support an athlete who is continuously evolving, the back-and-forth of exploration and understanding (i.e., hermeneutics) appears appropriate for indirect (i.e., movement-unspecific) support.

## 4. Conclusion

With its inherent deterministic properties, DST provides a mechanistic description of complex system behaviours *without* a dedicated control structure. In contrast, SPA is focussed on abstract representations and symbolic manipulations (including verbal input) in motor planning. Hence, these frameworks are incommensurable, each with their own advantages. More recent approaches do take the role of the body and the environment (both physical and social) into account, for example, embodiment, ecological psychology, and ideomotor framework. However, a combination of terminologies (of DST and SPA) may lead to confusing theoretical concepts and core assumptions (e.g., deterministic processes vs. openness to symbolic influences). A differentiation of terms, concepts, and frameworks is required for theoretical advancements. Regarding applied work, a wider perspective may include indirect support, that is, understanding the needs and the (whole) situation of the athletes. Indirect factors such as emotional support or motivational guidance are movement-unspecific but may be critical for (optimal) motor performance. Employing these factors requires a (qualitative) *psychological understanding* of the individual athletes and their personal situations. Thus, they may be construed as the cognitive future of motor control and learning.

## 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.

## Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

## Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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# Is premature theorizing hurting skill acquisition research?

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## Introduction

> *"…the dominant model of science in the field [that prioritizes experiments and hypothesis testing over real-world description] is appropriate only for a well-developed science, in which basic, real-world phenomena have been identified, important invariances in these phenomena have been documented, and appropriate model systems that capture the essence of these phenomena have been developed". [Rozin, 2001, p. 2]*

Debates about competing approaches to skill acquisition (specifically information-processing vs. ecological based approaches) have dominated recent conversations, both among academics and practitioners. Our central argument in this article is that the above referenced quote by Rozin (1), originally made in the context of social psychology, is equally applicable to the field of skill acquisition in sport. Focusing on the current state of empirical work, we argue that there is not sufficient empirical data to constrain theories in skill acquisition research, and that trying to choose theories based on such limited data is both premature and detrimental to the development of the field itself.

### What data constrains theories of skill acquisition?

A theory is only as good as the data it explains. For example, consider the difference between skill acquisition and a closely related research field like motor control. In motor control, there are examples of well-established invariances such as Fitts' law (2, 3) or spatiotemporal characteristics of reaching trajectories (4, 5). These robust and replicable phenomena provide such a strong empirical constraint that any new proposed theory of motor control is a non-starter if it did not account for these fundamental observations (6, 7). In stark contrast, it is difficult to think of any finding that poses such a constraint to a theory of skill acquisition in sport. Instead, most phenomena in skill acquisition are characterized by two features—(a) they tend to be highly context-sensitive (i.e., influenced by factors such as the type of task and the stage of learning), and (b) they tend not to have quantitative process-level descriptions and instead focus mainly on outcome measures. While context-sensitivity is perhaps a reflection of the fact that skill acquisition is inherently sensitive to the learner and the learning context as seen by concepts such as desirable difficulties (8) or the challenge point (9), this also means that literature is filled with fragmented and seemingly contradictory findings. Coupled with the lack of quantitative descriptions, this has meant that current theories of skill acquisition tend to live within little bubbles of data.

## Can we really choose between theories of skill acquisition?

However, despite the lack of robust findings, there is an attempt to follow the conventions of more mature sciences such as doing "strong inference" (10). Theories are often posed as being diametrically opposite on particular issues (e.g., "in theory A, variability is good for learning, whereas in theory B variability is bad for learning"). But while this contrast is helpful in that it raises awareness about the different ways in which we think about these phenomena, in most cases, theories are not specific enough to make predictions. In other words, there is no subsequent critical experiment which could distinguish between theory A or theory B because the question itself—i.e., "is variability good or bad for learning"—is ill-posed without knowledge of the context (e.g., the stage of learning, how much variability is being introduced, and what type of task is being learned) (11). In these cases, the strategy of having theories compete by constructing these binary oppositions is less likely to advance science (12).

Another major issue regarding the data is the question of how much these results matter in real-world conditions. For example, most motor learning experiments, often used as the basis for skill acquisition, still rely on constrained tasks that rarely resemble the complexity of real-world (13, 14). In addition, with limited sample sizes being an important factor constraining research studies, it is ideal in an experimental sense to maximize the effect size (i.e., the potential difference between groups) as much as possible. As a result, the contrast between groups is often exaggerated with "strawman" versions of groups that bear little resemblance to real-world skill acquisition (15). For example, the information processing approach has been associated with "prescription" of an ideal movement pattern (often borrowed straight from a manual) with no room for individual differences, variability, or real-time flexibility, whereas the ecological approach has been associated with a trial-and-error "self-organization" approach to finding a movement solution with no room for planning, instructions demonstrations, or explicit strategies. Under these circumstances, it is easy to see how, depending on the experimenter's theoretical view, one could design an experiment in a context that makes one theoretical view look better than the other. As a result, even when these methods are directly compared (16–18), many researchers and practitioners remain unconvinced about the impact of such evidence on real-world contexts.

## Discussion

We wish to emphasize that our goal is not to criticize theorizing itself. Challenging the theoretical status quo has brought important new perspectives to the field, which in turn has guided empirical data collection in new directions. For example, the focus on organism-task-environment as a whole (19) is an important perspective change on the role of the coach in terms of being "environment designers" (20, 21). However, in prematurely trying to choose between theories, or derive implications for real-world situations, there is a danger of overgeneralization based on phenomena that have mainly been observed in niche experimental paradigms. We suggest two recommendations for improving the discourse- from a researcher's view and a practitioner's view.

### Theory building with real-world constraints

From a researcher's view, we propose that instead of the standard hypothesis testing/falsification paradigm, skill acquisition is much more suited to the "inductive theory building" approach (22), which argues for building a "substantial body of data" across different real-world contexts (using different methods, participants, time spans etc.). In particular, there is a need for data collection outside of the domain of lab experiments, which tend to focus on extremely time-limited constrained observations, that by themselves are too rudimentary for theory building. The need for field-based data is a not new observation (1, 23, 24) but the continued lack of field-based data in guiding theories of skill acquisition seems to point to a systemic problem in what type of research is incentivized, and the need for large scale collaborations (including adversarial collaborations). In short, we need phenomena that everyone can agree on before we can test theories that people may disagree on.

For an illustrative example of such theory building, one might look at the development of Self-Determination Theory (SDT) over the past 50 years. SDT began with experimental designs to examine the effects of incentives on creative problem solving using SOMA puzzles (25). When these experiments showed that incentives undermined participants' willingness to engage with the puzzles during a break period, it questioned behaviorist tenets of the importance of incentives and reinforcement in volitional behavior and gave rise to the core construct of *intrinsic motivation*. Today, SDT is a "meta-theory" composed of six subtheories, each with an explanatory capacity for specific aspects of volitional behavior. Two features of SDT stand out as a model for skill acquisition. First, although SDT enjoys rather wide acceptance amongst behavioral scientists; few would argue that SDT accounts for all variance in volitional behavior, and few would neglect the effects of reinforcement, group norms, or other psychosocial factors in certain contexts. Second, SDT emerged from tightly-controlled, laboratory-based experimental designs, but then expanded to less-controlled, field-based quasi-experimental and even descriptive and qualitative designs. This expansion required scientists to sacrifice internal validity (afforded by experimental designs) for increased ecological validity (afforded by field-based research), which in turn allowed the theory to have an impact on a wide range of fields (26).

### Adopting a wider lens when critiquing coaching practices

From a practitioner's view, we propose that skill acquisition and the utility of different coaching practices be examined from multiple lenses. Often, there is a tacit assumption that evidence-based coaching requires complete alignment of the goals of the researcher and the coach. However, this assumption can be misleading since the objectives of the researcher and the coach are quite different—

researchers prioritize the search for systematic and generalizable principles whereas coaches are pragmatic and solution-focused. Recognizing this difference is an important aspect of the debate over skill acquisition and coaching practices and highlights the issue of why it may sometimes be non-trivial to translate research from controlled environments directly on to the field.

One example of how this difference manifests in practice is that a less optimal method of practice at one level may be preferred if it can be more efficient at a different level of analysis. For example, experimental comparisons of skill acquisition methods (such as blocked vs. random practice or constant vs. variable practice) assume that participants receive the same number of practice repetitions in each method. However, this assumption may not always hold in the real-world. With a fixed amount of practice time (which is typically the resource constraint), participants may often be able to do many more repetitions in a blocked or constant practice schedules because they require less changes in the environment and lesser effort from the coach. Similarly, certain types of isolated practice such as drills have been criticized because they remove the learner from the context. However, drills allow the coach to monitor several individuals at the same time. Therefore, as long as there is a non-zero learning benefit, some activities that seem suboptimal at one level (say the amount of learning/unit practice repetition) may actually be more efficient in terms of other levels (the amount of learning per unit time or per unit person-hours of coaching). Understanding these trade-offs at multiple scales of analysis is currently outside the domain of most experiments and highlights the need for more field-based work to complement lab-based work.

In addition, the solution-focused approach of coaches may also explain certain coaching practices. For example, many coaches still use an "ideal" movement pattern (e.g., that of an elite athlete) even if they do not believe in imprinting this movement pattern on the learner simply because there is no other alternative. Finding what the optimal pattern for a given individual is challenging even in the simplest of tasks because we currently do not have the framework to incorporate an individual's prior movement repertoire and preferences [cf. "intrinsic dynamics" (27)] into models of motor performance (28). Relying purely on discovery learning may be time-consuming and increase the risk of getting stuck in maladaptive movement patterns. A researcher faced with this problem has the option of choosing a different context that is more tractable for study, but this is not an option for the solution-focused coach. Therefore, using the elite athlete's movement patterns may represent a reasonable compromise in this scenario, as long as it is followed by a trial-and-error process to identify an individual's optimal solution. In addition, many pedagogical techniques may also be effective in that they satisfy different goals beyond skill improvement (29). For example, demonstrations are associated with increasing self-efficacy, reducing anxiety, and learning strategies or game plans (30). Although the above arguments are not meant as a general defense of all current coaching practices, it may be more fruitful to move debates away from "is coaching practice X important?" to "when is coaching practice X important?". Such context-specific answers may be unsatisfying to many, but may be a necessary precursor to a unifying theory.

In summary, we need a large and robust body of data to advance theoretical debates on skill acquisition in a meaningful way. One approach that may especially be fruitful in this process is the "informed curiosity approach" (1). Taking a middle path between the two extremes of hypothesis testing and simply amassing more data, the informed curiosity approach is characterized by attempts to answer open-ended questions that prioritize description of phenomena in ecologically valid contexts. For example, to understand the role of variability in learning, instead of a typical hypothesis-testing approach that compares two groups, an informed-curiosity approach would focus on describing the entire dose-response curve between variability and learning using multiple groups in a real-world task. Such descriptions of a functional relation between variables (31) provides a much better constraint on theory development than the two-group design where the nature of the result (both in terms of direction and effect size) is often highly sensitive to how the two groups are selected (32).

Given the much higher effort involved in collecting this type of descriptive data and the breadth of skill acquisition in sport, a first step is to identify a few representative contexts that can be the focus of immediate efforts. Even in the laboratory setting, the use of select "model tasks" has been proposed to reduce task fragmentation and strike a balance between internal and ecological validity (32). By identifying a small set of common tasks that can capture different aspects of skill acquisition (similar to how model organisms are used in biology), researchers will be able to compile data across labs and obtain larger sample sizes, which can potentially lead to the discovery of invariances (in the same mold as Fitts' law) that become the basis for theorizing. However, based on similar efforts in other domains (33–36), achieving even this first step requires coordinated large-scale collaborations between academic researchers, sport scientists, coaches, and athletes in a way that runs counter to the current model of conducting research within a single lab. Creating the infrastructure and the incentive structure for these types of collaborations may ultimately be the most important piece for a theory of skill acquisition.

## Author contributions

RR and AD contributed to the conception, drafting, and revising of the manuscript. All authors approved the submitted version of the manuscript.

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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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# Moving beyond skills acquisition: a multiple case study of situated learning in a league for children with disabilities

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In the last few decades, there has been a movement from individualistic and mechanistic notions of learning to approaches that turn attention to the significance of the context of learning. While these approaches have been utilized to point out the significance of the environment for skill acquisition, they have primarily been oriented towards performance-oriented milieus. Inspired by the theory of situated learning in "communities of practice" (CoP), the aim of the study is to analyze learning processes among members (participants, coaches, parents, etc.) of a diverse sporting community. The article is based on a multiple-case study of a Danish handball community named Lykkeliga (Happy League) that within a few years has attracted more than a thousand children with a remarkable diverse range of age, gender, diagnosis, and disabilities. The data collection included participant observation of training and tournament situations in two clubs over a 3-month period, along with informal interviews. The thematic analysis reveals a range of legitimate ways of participating for members of Happy League clubs, including sitting on the bench and even dating during practice. In sum, our case study sheds light on how situated learning in sporting communities may be directed towards inclusion and expansive understanding of what it means to be a sport participant.

KEYWORDS

handball, inclusion, community, sport, participation

## Introduction

Currently, many sports communities for children and youth have a dominating focus on promoting their abilities and performance (1). For instance, it has been empirically shown in a Norwegian study that competitiveness clearly structures youth sport (2). Such tendencies are not unique to sport but reflect larger societal discourses within youth culture (3). Within organized sports, children are categorized and grouped according to their age, gender, and abilities, and this is thought to facilitate their inclusion as well as ensuring fairness in sporting communities (4). Consequently, sport for children (with a range of abilities and disabilities) are often grouped according to their level of physical skills.

Such focus on abilities is also reflected in the field of learning and skill acquisition in sports, where researchers and practitioners are directed toward overcoming constraints in training so athletes can acquire skills (e.g., technical and tactical) (5). The primary perspective on learning as skills acquisition is linked with a traditional notion of sport participation, which assumes that "participants follow directions and are expected to execute the skills taught and trained as needed to compete" (6). While this focus on

learning may lead to sport-specific skill acquisition among athletes, it does not contribute to our understanding of how sports communities can facilitate learning among groups and individuals that tend not to participate in sports.

It is vital to understand what may facilitate not only access to sports communities, but the more continuous process of learning to become a participant in sport communities (7). This is a highly relevant topic since there is a great disparity in the degree to which and ways in which children participate in sport. For example, studies in the United States, Australia, the United Kingdom, and Denmark (8); (e.g., 9) have identified that children with disabilities participate at lower rates than the general population in all forms of cultural life, including sports (e.g. (10), Further, there are several studies indicating that the sport participation of children and youth with disabilities is often restricted with less enjoyment (11), less variety (12) and less likelihood of engaging in skill-based activities (13). In fact, accumulating evidence suggests that a range of environmental barriers such as institutional (i.e., clubs refusing to include athletes), social (i.e., labelling children negatively), and lack of support (i.e., too few staff and service providers) are some of the key barriers that restrict sport participation among children with disabilities (14–16). Thus, how sport communities organize and deliver sport is key to sport participation among children with and without disabilities.

This article aims to expand the current focus on learning as skills acquisition in sport through analyzing how sport communities may facilitate learning of what it means to be a sport participant. To do so, we study the case of the Danish Handball initiative "Happy League" that is frequented by children with diverse disabilities. Utilizing Etienne Wenger's theory about situated learning in communities of practice (CoP), we will analyze and discuss the variety of ways in which children with disabilities learn what it means to be a participant in the Happy League sporting community. In so doing, we seek to contribute to shift the focus from skill acquisition to situated learning, pointing to the options for members in inclusive sport communities to acquire experiences with diverse forms of sports participation.

## State of the art

In the last few decades, there has been a movement away from individualistic and mechanistic notions of learning within the sport sciences. While coaches have previously been meant to provide "pre-programmed optimal movement solutions" for athletes, the focus of practitioners and researchers has turned to more ecological approaches in which sporting practitioners are viewed as "sporting ecology designers" (5). Based on theories such as "ecology dynamics", researchers and practitioners have broadened the notions and practices of skill acquisition considerably by including attention to features such as the socio-cultural norms of the sporting milieu (17). While ecological dynamics have added more contextual perspectives to skill acquisition, the central tenet of the line of research is to consider how athletes can acquire sport-specific skills, and therefore how to design training and practice. For instance, through small case studies with an elite Australian Football League (AFL) team, Pinder and colleagues (18) showed how coaches can manipulate informational constraints within drills to direct athlete's attention to relevant affordances. From an ecological dynamic perspective, learning is viewed as "an ongoing dynamic process involving a search for and stabilization of specific, functional movement patterns" across the performance landscape as each individual adapts to a variety of changing constraints (19). While these contextual-oriented theories such as ecological dynamics have offered a nuanced understanding of how athletes can acquire skills, it seems to take athletes' *participation* in sport activities and their contexts for granted as it focuses on learning of specific "functional movement patterns" from a performance-oriented perspective. Thus, with such approaches, researchers who examine learning in sport may unintendedly strengthen the attention on how to facilitate sport performance in youth sport instead of how to facilitate participation in sport in general.

In line with calls from several researchers (20, 21), we argue that there is a need to turn toward learning theories that encompass an understanding of learning as structured around participation within sport communities. Grounded in the theory of situated learning in "communities of practice" (CoP), participation means more than simple physical engagement in certain activities, as participation is also the "process of being active participants in the *practices* of social communities and constructing *identities* in relation to these communities" (22). As such, participating in CoPs involves "…doing in a historical and social context that gives structure and meaning to what we do" [28, p. 47]. Consequently, we need to expand the conventional understanding of learning as skills acquisition (e.g., executing drills) to consider also how learning in sport communities may involve acquiring the meaning of sport participation.

There is a great potential in understanding how athletes are embedded in a larger social-relational context such as a CoP and how their skill acquisition may involve learning what it means to be a sport participant. As suggested, identities among sports participants are also acquired in CoPs that "can serve as conduits not only for learning, but also for transforming sport cultures into entities primarily concerned with developing athletes" (20). Consequently, the development of athletes involves not only performance and personal development but also participation in the sport (23). Based on an ecological framework, Cote and colleagues suggest that sport participation can have short- and long-term benefits for children's competencies, confidence, character, and connection. While these certainly are fruitful personal assets, they are highly attached to the situated learning in specific practices that children encounter. Until now, most studies utilizing a CoP approach have been designed as single case studies of specific sport clubs to reveal how situated learning occurs and what (adult) athletes learn explicitly and implicitly (24–26). However, several researchers have also examined how CoPs facilitated among coaches within and across clubs could enhance their learning individually and collectively (20, 26, 27). To our knowledge, no studies have investigated situated learning

among exceptionally diverse youth athletes across clubs, teams, or institutions based on a CoP approach. Further, studies with a CoP approach is often focusing on relatively homogenous groups that are similar in terms of age, gender, and abilities. Thus, in former studies of sport-related CoPs, the span in participation trajectories for newcomers or less abled members have been somewhat restricted, and the negotiation of meaning along with the construction of identities among members of the group have appeared alike.

## Theory

CoP is framed as a social learning theory; thus, learning involves social participation. The members of a community of practice will share and deepen their knowledge and expertise by interacting with one another on an ongoing basis (28). There are certain characteristics that define a community of practice: *mutual engagement, joint enterprise,* and *shared repertoire* (22). In a handball community, this could be a team training together (*mutual engagement*), wearing a club uniform (*shared repertoire*), and participating in sport towards a common goal (*joint enterprise*).

One of the key concepts in this theory is *participation*. Participation is both actions and a form of belonging. Thus, participation shapes not only what we do, but also who we are and how we interpret what we do (22). Social participation is therefore both a process of learning and of knowing that can be constituted in four components. The components comprise meaning, practice, community, and identity, which are deeply interconnected and mutually defining. Meaning can be learning as experience and is defined as our ongoing capability to experience our life and the world as meaningful. Practice is learning as doing as it is historical and social resources and our perspectives that can sustain mutual engagement in action. Moreover, community is learning as belonging which points to the fact that our participation is recognizable as competence. Lastly, learning is becoming as learning transforms who we are and creates identity.

In line with other learning theories, CoP assumes that only through participating can one learn from the given community of practice. However, contrary to other learning theories, Wenger developed a rich account of how people learn through participation in the community practices, and therefore suggests several categories ranging from participation to non-participation: *core group* (often a small group of persons whose engagement nurtures the community), *active participants* (members whose activity is recognized as significant and highly influence define the community), *occasional participants* (this group only participates when it is of special interest or they have something specific to contribute), *peripheral participants* (this group has a continuous connection to the community, but they have less commitment or authority within the community and are identified to be newcomers), and *outsiders* (persons who are categorized as not part of the community) (28).

As participation may be legitimate while also peripheral, Lave and Wenger (29, p. 36) acknowledge that there are "multiple, varied, more or less engaged and inclusive ways of being located in the field of participation defined by a community". Based on this theoretical perspective, the findings from a physical education setting show how students' participation or non-participation are closely related to the legitimacy ascribed to them by the environment (e.g., peers and teachers), along with the level of meaningfulness experienced by the students (30). Thus, each athlete's participation does not only depend on their perceived abilities but also relates to how peers and teachers interact.

## Material and methods

The ontological position in this research project was grounded in neo-pragmatism, as we sought to produce practical truths as those that prove useful within specific contexts (31). Therefore, this study does not seek to uncover reality, but to explore habits of action for coping with reality (32). In this project, the habits of action refer to the specific practices on and off the court that we were able to observe during our fieldwork (e.g., competitors applauding each other, players doing all kinds of things during practice, coaches using concrete artifacts in practice, etc.). As Richard Rorty (33, p. 173) proposed, the way to re-enchant the world is to stick to the concrete. Knowledge is not simply a matter of representing the world accurately but of guiding effective action. Accordingly, research may serve to generate novel descriptions of a topic or context to best position others to benefit from that information practically (32). In relation to our epistemology, we recognize that knowledge construction is contextual and inherently influenced by cultural, political, and historical conditions. As such, we will describe the broader context of the case we explore in the following sections.

The present paper is based on a quintain multiple-case study (34) as this study analyses a new Danish handball initiative called Lykkeliga (Happy League). A quintain is something that we want to understand more thoroughly, and we choose to study it through its cases by means of a multiple-case study (34). In line with a quintain approach, we acknowledge that Happy League is a target of our investigation but not a bull's eye as our fieldwork (besides official tournaments) only comprises two of the 78 club teams. Although each case (club team) was interesting to us, we focused on cases that could reveal embedded information about the quintain (Happy League).

Happy League was initiated in 2017 and since then has sparked the participation of approximately 1,200 new handball players with disabilities in 78 new club teams nationwide in Denmark. Happy League welcomes youth across age, gender, and abilities who do not feel they belong in the mainstream sport clubs. One of the few written core espoused values of Happy League is that the community is about much more than handball and that they encourage positive thinking and togetherness. The teams in Happy League are organized within traditional sport clubs and are widely dispersed geographically, including teams on the Faroe Islands and in Greenland. Happy League has used social media (Facebook, Instagram, and TikTok) to share their stories about their national and local initiatives with such success that

Facebook visited them in 2020 and posted a video about their community.

The data collection was based on field studies in two clubs over a 4-month period in one club and a 6-month period in the second club due to COVID-19 restrictions, along with 15 interviews with parents within seven clubs. In this article, we focus solely on the material generated during the field studies that were carried out in two clubs located in two different regions of Denmark.

Two local head coaches acted as gatekeepers who granted access for the first author and the research assistant to conduct field work in their clubs. During the field work period, the first author and a research assistant conducted observations of weekly handball sessions at two separate sites along with interviews with club officials and regular participants. At both sites, the Happy League teams were situated in traditional recreational clubs with teams ranging from Under 6 to adult teams.

Studies of children's sporting development (35) and, in particular, studies among children with disabilities (36, 37) clearly state that we easily consider children as our object of research, and therefore the voices of children are missing. Consequently, we were specifically interested in doing participant observation to learn from the children, as "*…to observe with or from is not to objectify; it is to attend to persons and things, to learn from them, and to follow in precept and practice*" (38, p. 61). As the children we followed had various disabilities, participant observation was the most suitable method to somewhat approach the children's' voices, as several of the children observed had limited or no verbal language. While our observations of children did not make us capable of replicating the exact words that the observed children said, it helped us understand what was meaningful for the children. As listening to children's voices can be defined as an active process of exchange of meanings (39), the participant observation was crucial to approach the children's perspective as near as possible.

Using "participant as observer" positions (40), we took on various roles during training; we instructed handball drills, fooled around with the players in the small breaks, had informal talks with parents and coaches, and took part in the games at the end of training as active coaches. Further, we were observers in several tournaments as this was an important part of the routines within the teams. This provided us with unique opportunities to engage in informal conversations, for example about participants' (both parents and players) reasons for engaging in Happy League, their participation trajectories, and to follow new players' inclusion into the team. Field notes were drafted during training and tournament sessions and written more extensively after field work, as suggested by Sparkes and Smith (40) along with Buch and Staller. Written informed consent was obtained from the players' legal guardian/next of kin. To ensure the anonymity of the interviewees, we removed all identifying information and assigned pseudonyms for each participant.

## Analytic strategy

We employed a reflexive thematic analysis in which the "researcher's reflective and thoughtful engagement with their data […] and the analytic process" was central in analyzing our field notes (41, 42). Inspired by Clarke and Braun (41), the first author reviewed the field notes prior to proceeding with an inductively data-driven approach, in which similar segments of text were first identified and grouped. Further, turning to a more deductive process, the first author reread the field notes and the segments of the text to possibly link the segments chosen to specific theoretical terms from the communities of practice approach. For instance, this process led to the theme *Learning through artifacts* as it is closely linked to the theoretical term reification. Hence, the first author organized the segments into broader and more manageable themes. These themes were carefully reviewed, discussed, and refined as a research team, which resulted in three themes.

To ensure qualitative rigor throughout this case study, we established and followed certain procedures. To establish credibility, the concept of crystallization was used to provide a complex, in-depth, and thorough understanding of this specific case study (43). Two researchers conducted field work to shift between multiple and consistent researcher viewpoints throughout the process. Peer-debriefing was used after each observation to purposefully reflect on their own preconceptions and ongoing interpretations.

The third author, who had intimate familiarity with the community due to another research project, assisted with member reflection during the observation period and in the period of analysis. Also, a member reflection between the first and third author and a leading person within Happy League was accomplished before the analysis was determined. Member reflection was aligned with the reflexive thematic analysis to provide an "intellectually enriched understanding through generating additional insights and dialogue" (44). Lastly, a leading figure of Happy League and the co-authors in this study also engaged as critical friends to facilitate rigor and quality through critical dialogue (44). The ongoing dialogues functioned as reflexive elaboration, ensuring that our interpretations of the data were challenged, and provided an opportunity to reflect upon alternative explanations or perspectives to enhance the quality of this case study. We now present the results of our analysis.

# Results and discussion

The following analysis is split into three parts. Initially, we point out how centrally designed artifacts within the community facilitated *Learning through artifacts*, which helped athletes and parents to learn sport-specific skills and unite athletes, parents, and teams. Secondly, we focus on how coaches, parents, and athletes were *Learning to be inclusive* on and off the court. Thirdly, we reveal how the community enabled practices so all involved were *Learning that sport participation comes in many forms.*

## Learning through artifacts

Already in the first visits to the clubs, we noted that Happy League fosters a shared repertoire across coaches, parents, and

players by promoting appealing distinct physical requisites. For instance, an identical Happy League logo was used on various jerseys across the club teams and was something that was striking for the author from the very first observation day. During our field work, we realized that these symbolic artifacts not only functioned as a shared repertoire, but that the members of the community were learning an extended notion of sport participation through artifacts. During an informal interview with a local coach, it became clear, that the Happy League logo reinforced to members (e.g., athletes, coaches, and parents) that they are part of a larger community across gender, age, disability, clubs, and even countries.

> When we went to the Happy League tournament last time, we were a large group of people and went there the day before to be properly ready for such a big day. Since we came early, we went for a stroll down a pedestrian street. At some point, we saw a small group of people going directly toward us. Within the group, this one guy with a Happy League shirt smiles and starts to hug us. All. He was from the Faroe Isles, and was not able to speak, but was so glad to meet other Happy League people, which he could figure out we were as we, of course, also wore our own Happy League shirts. (Field notes from first author, 31/1–2022)

Through the community-designed artifacts, members of the club teams non-formally learn that they are not only competitors, but are also embedded in a larger community with similar interests such as having fun and being together. From a theoretical point of view, concrete artifacts are a way to facilitate reification, which means to project our meaning into the world through objects such as a logo (Happy League logo). As Wenger points out, reification and participation enrich other (45) and function in a dialectical relationship. While the mascot-like artifacts seem to be positive inputs occasionally, the logo is an integral part of the everyday life of the members of the group. Some of the athletes wore their shirts with the logos all the time (i.e., at school, home, and during sport) as this probably presents an important part of their identity. Thus, the logo also facilitates their participation on as well as off the court. Contrary to the previous studies utilizing the CoP framework (26, 46), the community-designed artifacts in this case play a significant role in symbolizing this embeddedness, and as shown in the observation, function as a way of connecting members within but also across club teams. The concrete community-designed artifacts carry varied functions, as a mascot named Happy-Lars mostly spreads a happy atmosphere at tournaments but also tours across club teams to spread joy to the children.

The community-designed artifacts are also highlighted within a Happy League initiative in which all players are selected to the "biggest national team in the world". Practically, this means that each athlete has been officially selected to the national team of Happy League, symbolized in them receiving a national Happy League shirt and invitation to monthly regional national team practices across club teams. Thus, several players in one of the club teams wore national team jerseys, went to the national team practices together, and also felt a certain belonging to this community.

> Before the training session begins, a coach walks over to me and introduces himself. Jarvis is the name. While we chat, a player named Joe, walks over to Jarvis and shakes his hand. "Welcome to the club, Jarvis. I am the captain for the team," Joe says, while he first points at the armband and then the logo of the club on his shirt. "Well, that's good to know, Joe," Jarvis replies. Joe pulls up his shirt and shows of his national team jersey and says, "And I am also captain for the national team." (Field notes from first author, 14/2–2022)

The national team seems to serve as an artifact symbolizing that all members within the Happy League community have equal access to participation. In this sense, the community transcends the notions of a traditional national team, selecting those with the highest abilities. Furthermore, through such practices, members of the community learn that they are legitimate members of the community no matter their level of abilities and disabilities. Such an apparently unlimited inclusive approach in the Happy League community will be described in more details below.

## Learning to be inclusive

While the training directly focused on sport-specific competencies, we learnt through observations and informal interviews with coaches, parents, and Happy League staff that participants within the community informally learned to be inclusive. While all the members were deliberately focused on the children's abilities to learn to catch and throw the ball in the training activities, learning to be inclusive certainly seemed to take place more informally, though the inclusive approach was still omnipresent in all their activities across members (e.g., coaches, parents, and players). Using Wenger's terminology, the analysis suggests that learning to be inclusive is a vital part of what can be called the CoP's joint enterprise. During our field work in two Happy League clubs, it became quite evident through observations and informal interviews that their joint enterprise could be understood as creating a fun and inclusive handball community. As such, the participants' legitimacy is not linked to how they perform or even participate in the activity but simply with the fact that they join in the activity in some way. Seeing that the goal was to create an inclusive handball community, the way activities were structured taught children how to be inclusive. This was evident at both training and tournaments, and on and off court. The inclusive approach was emphasized, which showed a high degree of non-formal learning within the activities on and off court. During training, the players learned to adapt their passes and revise the rules within the handball game to ensure that all players could participate:

> When a playful warm-up is over, there are multiple players who say "cue ball" or "aren't we gonna play cue ball". "Ok,"

> the head coach says. She starts cue ball with all coaches and players… Large and small (players) are part of the game. The large hard-shooting boys shoot with full power, but never against the small ones. There is an understanding of who the boys can shoot full power at, and who to shoot slowly at. At a time, the youngest takes ten steps, and starts counting on the seventh step, one, two, three. It does not create conflict. The game is on. (Field notes from research assistant, 3/2–2022).

Since Happy League invites all players that do not feel they belong in traditional clubs, they have players with high handball competencies and no labelled diagnosis on the same team with players that sit in a wheelchair or have difficulty running, walking, or catching a ball. As such, coaches informally facilitate that members of the community learn to include every teammate and even opponents in the community established around training and match practices.

> In the matches during training, the coaches, including myself, act as a kind of playing coach. There are playing coaches on each team that all ensure to bend the rules according to the players' individual needs and skills. The coaches defend extra hard against Nathan and rule ordinarily (e.g., maximum three steps) when he has the ball. Mason stands a little confused on the pitch in his first training and seems to observe the coaches' ways of regulating the game. Mason takes four, five, six steps and throws the ball toward the goal and scores, yet the coach does not rule against him. Nathan asks the coach: "Wasn't it a foul?" The coach replies: "There are no fouls on Mason today, but you only have three steps, Nathan". Nathan looks up, and nods accepting, but also looks a bit frustrated. (Field notes from first author, 29/11–2021)

Our observations show that the practices within Happy League constitute how players learned personal competencies such as empathy *because* of the diverse heterogenous group of players within the community.

> "He has learned to be really good at taking the youngest into consideration when he plays, adapting his passes, taking good care that everyone is included. So, the fact that the athletes have various ages and gender does not stand in the way for him?" I ask. "No not all, on the contrary," the dad says. (Field notes from research assistant, 17/11–2021)

While the coaches certainly were guiding how to be inclusive within the club teams, the parents and even the children also constituted such notions and practices during training session.

> The head coach has not been at training for a long time, and she tells the athletes how much she has looked forward to seeing them. Maybe she can't remember all of their names, she says while she smiles cheekily. "We better start with a round of names", one of the big boys says returning the coach's cheeky smile. They start to do a round of names. "The adults, too," one of the boys says, when the head coach intentionally misses one of the parents. All, including the parents, present themselves while they look into each other's eyes, and then they are ready to play handball. (Field notes from research assistant, 3/2–2022)

Such practices were also evident in the largest tournament within the community, Happy Cup, as players had to register themselves as participants, which led to teams being formed for the tournament across the traditional club teams. This provided many players with the opportunity to play and get to know various players from other club teams, but also to learn to meet new people guided by coaches and parents. Thus, within this community, it seems that the coaches not only design drills that enable players to learn handball-specific drills, but the coaches and parents also co-create a community in which they enable players to learn to be more inclusive towards the vast diversity of players within the community. The inclusive approach was clearly not just a personal asset that the children learned (as well as coaches and parents), but also positively influenced the unity within and across teams and the participation trajectories of especially the newcomers as they rapidly felt welcomed and part of the community. These findings are similar to those found in a study among adult swing dancers, since the dancers quite freely pointed out in interviews that swing dancing was a "great opportunity for social levelling" (46). Similarly to handball, swing dance also encompasses competitive activities, central members within the swing dance community emphasize that swing dancing is not a sport *per se*, but rather an opportunity to be together and have fun. This suggests that despite the ingrained, competitive nature of sports, the emphasis from central members within a community may have the potential to inspire newcomers' meaning-making of their engagement in the sport.

## Learning that sport participation comes in many forms

Finally, the analysis reveals that members of Happy League learn that sport participation can take many forms. During our field study in both clubs, it was accepted by coaches and parents that players went for a break in the lobby, sat on the bench for the whole training, or dribbled and played for themselves during drills. This again, relates to the joint enterprise. As we wrote in the previous section, joint enterprise could be seen as creating a fun and inclusive handball initiative; meaningful participation is linked to joyful and legitimate participation, and not with winning/losing and/or skill acquisition. The coaches allow for many new opportunities for legitimate participations that in a different CoP might have led to exclusion instead. The following extract from a field note shows the legitimacy in the various ways of participating during training:

> During the classic warm-up, Kayden walks over to and hugs me tightly, a real bear hug, with both his arms swung around me while he cheekily laughs. Previously, we have only said "hey" to one another. After a long firm hug,

> Kayden starts to wrestle with me by laying his arms around me in a firm position. Kayden cheekily smiles (he hasn't got much verbal language), while he wrestles me to the floor… The assistant coach, Jarvis, walks over to us, and I expect that he will ask us firmly to stop. Instead, he asks "Are you ok?" I look bewildered at him and says, "Yes, of course". Kayden laughs and pulls me down on the floor again, while he holds my hands firmly to the floor. Suddenly, a girl, Cathryn, who is wearing a dressed-up outfit, not handball clothes, walks over to us. She asks quietly if Kayden wants to go outside. Kayden says "yes" while smiling. They walk quietly outside the arena, while players and coaches are focusing on drills. After five minutes, they enter the arena again hand in hand, and immediately Kayden runs over to me. I ask Kayden, "What have you two been up to?" Kayden answers that Cathryn has given him a boyfriend/girlfriend present. I answer that it sounds wonderful, while I can see his girlfriend walk towards the goal in her dressed-up outfit to participate in a new drill. (Field notes from first author, 06/12–2021)

Indeed, our observations show how all players were considered *legitimate participants* no matter what they were "practicing". Although previous studies within disability sports have problematized that people with disabilities are framed as *viewers* rather than *doers* in recreational and sports settings (47, 48), our observations suggest that such roles often function as starting points for an *active participation* eventually, and also function as a pause from sport when needed. Such positioning in what might be considered peripheral roles appears to be legitimate way of participating in the handball community that is accepted by coaches along with parents. For instance, although Cathryn could be labelled as an *outsider* and a *viewer* in the beginning of the above mentioned training session, she had a meaningful non-sport task to complete before she took up the position as an *insider* of an organized sport community. Thus, by making it legitimate for participants to take up a variety of unconventional roles as sport participants that do not involve being physically active all the time, the Happy League community seems to constitute trajectories for the athletes toward sport participation.

> Karl is really happy to play in (the club team), the dad explains. "There's room for all kind of children. We have tried with swimming in the local club, but we were kicked out," the dad says. "We offered to be in the water with Karl, but that wasn't an option, so Karl couldn't stay on the team. Karl needs adult support. He gets that here, and at the same time there is room for him and a lot of other different children," the dad says. (Field notes from research assistant, 08/12–2021)

During tournament games, we have also witnessed players taking the roles as judges, eating a hotdog while being in defense, chatting with opponents, taking a role as an assistant judge, while both parents, coaches, and judges were acknowledging their various forms of participation. These occurrences also clearly show that the competitive nature of the matches have been downscaled considerably compared with other sport communities (20), but also that the sport community legitimize various ways of participating as the coaches are not rewarded according to their win–loss records, but rather their way of including various players and creating sustained sport participation among them.

## Conclusion, limitations, and recommendations

In this article, we have shown how it is possible to shift the narrow focus on skill acquisition in youth sport toward situated learning, highlighting the possibilities for members in inclusive sport communities to acquire experiences with diverse forms of sports participation. As we highlight in our state of the art, many studies have either taken athletes' participation in sport activities and the meaning of the context for granted because the main objective has been driven by a performance-oriented focus or, if inspired by a CoP-approach, the studies have been on homogenous groups with little to no attention paid towards participation trajectories for newcomers or disadvantaged members. Based on Wenger's concepts of situated learning within communities of practice, this case study broadens our conventional notions of sport participation by showing that participation can take many forms, even in a highly heterogenic group of young athletes.

In our analysis, we identified three central components that made it possible for the participants to learn in various ways within the community. We argue that centrally designed artifacts facilitate the participants learning as they aid athletes and parents to learn sport-specific skills while also uniting athletes, parents, and even club teams across the countries. In our analysis, we also showed how sport participation can encompass non-physical activities during training or skill training outside the handball arena. The findings show how the players learn to play handball in a community in which competition is not ubiquitous. On the contrary, because the focus was on participation and *not* performance, players were able to learn to be inclusive while competing.

While Happy League is an inclusive sport initiative aimed at children and youth with disabilities, the approach that they have to learning and participation is not limited toward disability initiatives. The focus on competition, performance, or even enhancing sport-specific skills in youth sport in general, possibly restricts children and youth from starting participation or even dropping out at early stages. Thus, the approach to sport participation that we have presented using the case of Happy League has the potential to inform and inspire other sport systems that may be single-mindedly focused on skill acquisition, athletes' abilities, competition, and doing sports physically while they forget to nurture athletes' identity, their relationships, and the community encompassing the athletes.

## 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 humans were approved by Den Videnskabsetiske Komité for Region Nordjylland. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

## 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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## 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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# Reconceptualising knowledge in the athlete–coach learning system: a mixed-method case study of harnessing bi-directional self-organising tendencies with a national wheelchair rugby league team

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Knowledge and knowledge transfer are often viewed in unitary and hierarchical terms, where a linear transaction exists between an individual possessing a body of knowledge and a person needing that knowledge. Although this traditional view of knowledge transfer is common within the sports domain, it is problematic because knowledge is treated as a self-contained entity. The overarching purpose of this study is to explore the ecological role of knowledge, underpinning performance preparation processes in an international coaching setting. Specifically, we investigated how bi-directional self-organising (coordination) tendencies (coach and athlete-led) can be exploited to facilitate the formation of attacking synergies within the team sport of wheelchair rugby league. A mixed-method case study approach was employed to collect data, involving semi-structured interviews, reflexive observations and field notes, and notational analysis. Results from the study described the transitional process of positioning an ecological view of knowledge transfer as a guiding principle to enhance athlete and practitioner collaboration. This reciprocal relationship provided documented opportunities to enhance on- and off-field team synergies. The pedagogical experiences we describe emerged throughout periods of uncertainty, requiring effortful interactions, forged on the continuous coupling of key agents (individuals), content, and context, enabling application, refinement, and opportunities for team synergies to evolve in performance preparation. Results suggested that the challenge of understanding and facilitating knowledge transfer could be embedded within the ecology of a complex adaptive system, sustained as a contextualised activity reciprocally constructed through on-going correspondence between athletes, scientists, practitioners, and the competitive performance context.

KEYWORDS

ecological dynamics, complex adaptive systems, knowledge transfer, team synergies, bi-directional self-organisation tendencies, constraints, principles of play

## Introduction

Game-play strategy, practice designs for performance preparation, and feedback provision in team sports are essential processes that have been traditionally coach- or teacher-led. Operating in a hierarchical *top–down* approach to explicitly instruct athletes and direct tactical strategies, in what has been termed deliberate practice (1–3). Top–down tendencies are still pedagogically prevalent across sports, even though these approaches have attracted criticism because of the mechanistic foundations of performance suppressing the autonomy of athletes (4, 5). These insights on traditional pedagogical trends are not limited to academic researchers. A notable practical insight aligning with this strong pedagogical tendency was revealed by a New Zealand All Black rugby union player (6), when reflecting on his experiences of performance preparation at the Racing 92 club:

> One of the biggest surprises I had when joining Racing was that everyone did what the coach said. In team meetings, players would not say a word … I had to bite my tongue. There was no awareness of playing what you see. My career has been about backing my instinct and being prepared to go against the gameplan.

Not all pedagogical approaches are predicated on traditional, explicit, coach-led game-play strategies, and a large body of literature advocates the (re)conceptualisation of team sports as a complex adaptive system (CAS) (7). In a CAS, athletes, coaches, support staff, and the environment are mutually entwined and reciprocally influence performance behaviours towards achieving a specific goal (8, 9). This (re)conceptualisation of performance in team sports is founded on a complex systems view of human behaviour, describing how collective team play and tactical formations emerge under specific constraints (10, 11). During a team sport competition, surrounding constraints (e.g., tactical principles of play) can facilitate the co-adaptation of players to form rich patterns of behaviour that configure synergy formation (e.g., combining actions) between players (12). Whilst satisfying a range of constraints, individuals differentiate between sources of information that can specify relevant affordances (their opportunities for action), available to be utilised during a competitive performance (13). Individuals and teams with the functionality to select relevant affordances whilst satisfying constraints are likely to have the adaptability to solve performance problems and regulate their actions supported by the guidance of an external source (e.g., a coach). However, despite a growing body of research conceptualising teams as CAS, case studies documenting how practitioners have used this concept as a framework to inform their practice are lacking (14).

Without these important applied insights on contemporary approaches to practice, longstanding issues will remain. For example, a challenge for coaching practitioners is understanding how to provide conditions in practice and competition that support athletes in satisfying global constraints (e.g., prepared game-play strategies) and local constraints (e.g., co-adaption between teammates as contexts change) for enhancing synergy formation. Although there has been a traditional tendency to polarise these two dichotomous positions within an applied practice, Ribeiro et al. (15) provided a substantial theoretical rationale suggesting that global-to-local (e.g., top–down) and local-to-global (e.g., bottom–up) self-organisation (coordination) tendencies can *co-exist* and be intentionally integrated to enhance performance in team sports. Ecological dynamics emphasises that these bi-directional tendencies exist on a heterarchical continuum. Framed in a more flexible approach, coaches and athletes may conceive less rigid global influences as *principles* to guide intentions and actions of players in team invasion sports (e.g., advance forward, attack space between and behind defenders, and support the ball carrier can form the basis of attacking play). Using coach and athlete interactions to co-design practice tasks can facilitate the formation of stronger, adaptive, and less predictable synergies between players (16). More fluid global influences of this nature support players to co-adapt their actions under localised sources of information (e.g., immediate teammates and opposition actions), therefore becoming less reliant on global and explicitly pre-determined ideas. From a CAS perspective, the process of synergy formation in the athlete–coach–environment system means that spontaneous changes in competition increase the probabilities for adaptive behaviours to evolve (17). With this tendency in mind, training programmes must be flexible, contain uncertainty, and offer opportunities for local-to-global self-organising tendencies between players to emerge and strengthen athlete–coach–environment interactions (18).

Regardless of these advances in understanding bi-directional tendencies in team sports performance, there are few examples of how coaching practitioners have implemented these theoretical insights in practice. A reason for this paucity could be the challenges associated with transferring sports science research, theory, and data into applied practice. For example, Buchheit (19) argued that some sports scientists may lack sport-specific knowledge to appreciate the performance problems that need solving. Indeed, this dilemma has stimulated a wealth of academic publications that have aimed to unpack the nuances associated with applying research into practice [e.g. (20)]. However, all too often, scholarly activity aimed at understanding this challenge creates a false dichotomous view of the disconnect between the academic world (e.g., research to satisfy universities' strategic objectives that may have little applied value to practitioners) and research that can support practitioners to solve immediate performance problems (19). Whilst this point has been well made, rather than viewing theory and practice in binary terms, time may be better spent exploring how the closely connected and intertwined nature of theory and practice can facilitate the reciprocal exchange of empirical and experiential knowledge, which can support the generation of performance solutions in competitive sports contexts. As Ross et al. [(21), p. 2] have commented, bridging the research–application divide is an immediate challenge that needs attention from both sports scientists and coaching practitioners to provide an "integrative

blend of evidence-based practice and practice-based evidence". Better research–application integration can aid sport performance practitioners in answering fundamental questions that provide insights into what conditions may facilitate creative and functional behaviours for high performance.

To that end, this paper aims to explore the challenge of knowledge transfer in a high-performance coaching setting. More specifically, we sought to address the calls of Ribeiro et al. (15) to explore how the application and interplay of bi-directional tendencies can be harnessed for the self-organisation of emergent attacking behaviours in a team sport. Academic contributions have provided detailed theoretical insights into bi-directional tendencies. However, to date, no empirical studies have positioned a bi-directional synergy formation approach to training and performance preparation. Whilst current contributions to the CAS literature provide the academic community with theoretical insights, little effort has been made to support sport scientists and practitioners' understanding of how local-to-global tendencies can be harnessed to develop adaptive team performance, diversifying tactical patterns of behaviour as competitive performance conditions change (15). Difficulties associated with implementing studies of this nature in real training and competitive contexts (e.g., time constraints, squad availability and access, and coaches' authorisation) have limited the understanding of contemporary applications. Therefore, this study offers a novel contribution, hoping to motivate sports scientists and practitioners to implement future studies that explore novel approaches to performance preparation based on bi-directional synergy formation. To achieve the overarching purpose, a mixed-method case study approach was deemed appropriate to address the following aims: (1) document the experiences of the first author in creating conditions that facilitate a balance between bi-directional self-organising tendencies in a high-performance sports setting; (2) explore how the reciprocal interactions between players, coaches, and contexts shape the emergence of team synergies; and (3) collect and analyse performance data to provide an additional opportunity to facilitate the exchange of reciprocal knowledge between players and coaches. Typically, performance analysis methods remove the athlete from the process, rendering them redundant and mere recipients of information to critique their performance. More specifically, aim (3) used descriptive analysis to encourage stronger interactions between the wider coaching team and the players to discuss and evolve how implementing bi-directional tendencies can facilitate attacking strategies.

# Materials and methods

## Research design

Although there are different ways to face the challenge of understanding the knowledge transfer process in sports, this study chose the mixed-method approach to provide flexibility in using quantitative and qualitative methods to address the common research goal (22). In addition, a case study design was selected because, as Simons [(23), p. 21] suggested, a "case study is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, program or system in a 'real life' context." More specifically, in the same way that Hodge et al. (24) examined the motivational climate created by the New Zealand Rugby Union team, an instrumental case study was undertaken to achieve that purpose. The Sheffield Hallam University ethics committee provided ethical approval. The data collection period spanned two and a half years. It involved collecting data from casual conversations, semi-structured interviews with the athletes, first author reflexive observations and field notes, and analysis of performance statistics collected from international fixtures.

## Positionality and reflexivity

At the outset, it is important to acknowledge that the first author's (in)experience as a coach and academic will play a significant role in the production of this research. Whilst many years of working in coaching, coach education, and player development provided MR with a physical–cultural insider status, providing many advantages in securing access to the field (25), it also presents considerable challenges regarding researcher subjectivity. In addition, MR's practice (together with the co-authors' theoretical persuasion) was informed by an ecological rationale of sports performance, positioning athletes and teams as complex adaptive systems who self-organise their collective performance behaviours (9) under interacting task, organismic, and environmental constraints. We acknowledge that because of the history and theoretical positioning of MR, interpreting experience (and data) can never be free of value. However, as Blackshaw (26) argued, these biographical experiences enable the interpretation of the phenomena under study. To challenge these subjective assumptions and accept that the research team cannot be detached from the research process, all stages adopted reflexive practice. This approach included facilitating discussions with players, coaching and professional support staff (other insiders), and academic colleagues who were outsiders to wheelchair rugby league, intending to maintain a critical and reflective perspective. Standing back from the analytical process and being reflexive and self-critical supported the research team in providing methodological rigour, challenging their theoretical assumptions and analytical conclusions (26). Adopting reflexive practice provided opportunities to question theory, reflect on our own assumptions of practice design and performance preparation, and be self-critical towards our interpretations of the qualitative findings [e.g. (27)].

## Context and background

The first author (MR) was situated as an assistant coach with a national wheelchair rugby league team, a sport played by mixed physical ability and mixed gender athletes. MR joined the coaching team in January 2020 and was tasked with preparing

the playing squad for the 2021 World Cup competition (played in 2022 because of COVID-19 restrictions). The old coaching team had been overseeing the development of the playing squad for the previous World Cup cycle (4 years), and all previous performance staff were no longer part of the new coaching group. Initial observations of typical practice and competition performance tendencies (influenced by the old coaching team) and casual conversations with players indicated that practice designs and match play tactics were dominated by a global-to-local direction. This approach to practice was characterised by a strict adherence to a structured game model where rigid, predictable, and inflexible on-field behaviours limited the co-adaptation and emergence of synergistic relations between players. For example, during the attacking phases of play, specific players advanced the ball to precisely specified positions on the field of play, pre-determined by a numbering system (e.g., the pitch was split into channels, numbered 1–5 from left to right). Once a player had advanced the ball to the "correct" pre-determined position, they became redundant during play until their next pre-planned involvement.

Initial observations of this approach suggested that it was over-orchestrated, with the propensity for global system behaviours to explicitly over-constrain player interactions and co-adaptation in a top–down fashion. Overvaluing the influence of global-to-local tendencies made some of the current playing squads assume that they could not be the source of their own activity. In other words, the players believed that they could not effectively interact with the opportunities for action that emerged in competition without the explicit instructions or guidance of the coaching staff, or a rigid game model [for a theoretical explanation of human behaviour in ecological psychology, see (28)]. Indeed, the existing performance model failed to exploit bi-directional self-organising tendencies, disengaging some players from the learning, development, and performance preparation process.

Several months before the case was studied, the new coaching team and players began to facilitate performance preparation for the international competition by introducing the key idea of exploiting both bi-directional tendencies in practice and competition. More specifically, the previous structured and rigid game model was refined, and attacking team play and practice designs were based on flexible principles of play (termed *Go Forward with Support*) co-created by the players and coaching team [which included guidance to work in pairs, explore, and vary play to play (early pass, change of direction, and tempo); all players "stay alive" on every play]. Coach observations and athlete insights of this approach indicated that local interactions were heightened through players being given more freedom to explore the global principles of play, according to their unique capacities and characteristics, which ultimately afforded greater synergy formation at a local level. A critical factor in this process was drawing on the rich experiential knowledge of this group of international players to identify these principles. Adopting this approach allowed the players to share their detailed insights of the game. Therefore, principles were based on the needs of the players, action capabilities, *knowledge of* the performance environment, and its affordances in competition [e.g. (13)]. Woods et al. (29) conceptualised this approach as *representative co-design*, suggesting that drawing on an athlete's experiential knowledge is vital in strengthening local self-organising interactions between teammates and opponents, an important factor in enhancing team synergies (30).

## Participants

The participants were all part of a national wheelchair rugby league team preparing for the 2021 World Cup competition. The age of the athletes ($N = 14$) ranged from 18 to 36 years ($M = 28.3$, SD = 6.18), and international appearances ranged from 6 to 30 games ($M = 18.9$, SD = 8.25). Prior to data collection, the proposed research period was presented to the players during a team meeting. Following a series of questions about the study, all participants provided informed consent before data collection took place.

## Semi-structured interviews

Semi-structured interviews were selected as one data collection method so that MR and the players could co-create insights relating to the aim of the study (31). Individual interviews were conducted face-to-face with all 14 players and ranged from 35 to 80 min in duration ($M = 56.8$, SD = 13.4). Interviews were conducted with the players between September 2021 and September 2022, prior to the start of the World Cup competition. Some interviews were conducted during training and competition periods, with others taking place away from formal settings. Approaching the interviews this way ensured all players had time to experience the balanced approach between self-organising tendencies in practice and competition. During data collection, all interviews were audio-recorded and transcribed verbatim. The specific purpose of the interviews was to explore the participants' experiences of practice and match play conditions that facilitated performing under local-to-global self-organising tendencies. The interview guide posed questions relating to general experiences (e.g., "Can you tell me about your experiences of playing without a structured game plan?"); more focused experiences, such as individual changes (e.g., "Has playing without a structured game plan changed how you see and act on opportunities?"); and interactions with teammates and opposition players (e.g., "Have you noticed any changes in your interactions with teammates and opposition players?"). In addition, probe questions were used to explore these areas and player responses in further detail.

## Reflexive observations and field notes

Reflexive observations and field notes were used in conjunction with the semi-structured interviews to develop a deeper understanding of facilitating a balance between bi-directional self-organising tendencies (32). Observations occurred before, during, and after training sessions and competitive matches, in

team meetings, and during video review sessions. All these settings presented an opportunity to observe players, coaches, and support staff reactions, comments, attitudes, interpretations, acceptance, and resistance to practising and performing under bi-directional self-organising tendencies [e.g. (33)]. Immediately after these events, field notes were made away from the team environment (e.g., hotel room, quiet areas at the training venue, and a local café) to record observations and experiences pertinent to the aims of the study. Whilst reflexive practice was a golden thread throughout all stages of the research process, it was important here so MR could reflect on how his subjectivities and theoretical assumptions informed interpretations of observed events [e.g. (34)].

## Performance analysis

Notational analysis was conducted to examine how attacking synergy formations emanating from both bi-directional tendencies influenced collective defensive behaviours. Recordings from four international games were analysed. The attacking team play from two of the games analysed had a strong global influence (under the previous coaching team). The other two games represented attacking team play favouring more local-to-global self-organising tendencies (the team had been performing under more local influenced play for approximately 12 months prior to data collection). A total of 204 tactical events were sampled across the matches, as these fulfilled the criterion of having complete data for every event series.

## Notational analysis

The notational analysis data were recorded using an *ad hoc* observational instrument created in Nacsport. To ensure the stability of notational data, the observational instrument was developed using operational definitions (**Table 1**) and indicators of key performance adapted from empirical research on rugby union (35). It is important to note that an optimal value on defensive positioning cannot be achieved since the interaction between attacking and defensive situations changes from second to second. Regarding defensive stability, we operated within a bandwidth of suitable actions. For example, a player facing their own goal line or not part of the defensive line would be coded as an unstable defensive position. Video footage of each game was scrutinised using freeze frame functions and playback speed in Nacsport, allowing all tactical actions to be compared against the operational definitions (36).

TABLE 1 Operational definitions.

| | |
|---|---|
| **Defensive stability** | |
| Great instability | Two or more players are out of position when the tackle is made or when a play the ball is completed to restart play. |
| Moderate instability | One player is out of position when the tackle is made or when a play the ball is completed to restart play. |
| Stable | No players are out of position when the tackle is made or when a play the ball is completed to restart play. |
| **Tackled by number of defenders** | |
| Tackled by one defender | A single defender committed to tackling the ball carrier. |
| Tackled by two defenders | Two defenders committed to tackling the ball carrier. |
| Tackled by three defenders | Three defenders committed to tackling the ball carrier. |
| **Play the ball** | |
| Play the ball | The play the ball consists of the tackled player facing the opponents' goal line, placing the ball on the floor, and promoting the ball backwards. The ball is deemed in play when it moves backwards. |
| Play the ball speed | The time it takes for the play the ball to be completed. |

## Data analysis

### Reflexive thematic analysis

Data collected through field notes and semi-structured interviews were analysed through reflexive thematic analysis (RTA) (37). Using this approach, MR engaged in a reflexive, thoughtful, and non-linear manner to generate themes related to the study aims (38). An important point to note here is that for researchers working with RTA, the aim is not to provide "accounts of accurate or reliable coding" to generate a single truth but to spend time immersed in context and data to systematically interpret information and generate themes [(37), p. 1393]. As such, Braun and Clarke's (39) six-stage approach (e.g., familiarisation with the data, generating initial codes, generating themes, reviewing potential themes, defining and naming themes, and producing the report) served as a framework to support an iterative process, where semantic and latent coding was used for theme generation. More specifically, and in no particular order, MR would read transcripts multiple times, make and revise notes, consult with interviewees when clarification was needed on specific themes, refer to theory, and share ideas with the co-authors to scrutinise and develop themes. Through this process, a final set of themes was generated.

### Performance analysis data

Descriptive analyses were employed in Microsoft Excel to calculate absolute frequencies for each variable. Using descriptive statistics during the analysis aimed to provide clear and collaborative coaching practice. In contrast to using inferential statistics indicating an association or difference between two or more variables, descriptive statistics were considered more effective in displaying data to the coaches and players because of the ease of summarisation and interpretation of data (40).

# Results

## Observations, field notes, reflections, and notational analysis

This subsection presents findings that combine the first author's observations, field notes, reflections, and performance analysis data to document the facilitation of a learning system to

introduce bi-directional self-organising tendencies during practice and competition. As such, this subsection will adopt a predominately first-person perspective to reflect personal experiences of this challenge. The lived experiences of MR are presented to highlight the value of working through an athlete–coach learning system to challenge the status quo, and how generality and specificity of practice, and notational analysis data encouraged a balance between bi-directional tendencies in training and competition.

## Enhancing player and practitioner collaboration through transdisciplinary practice

When a coach is faced with the challenge of changing deeply rooted socially and culturally informed ways of performing and preparing, they have to make several tricky and important decisions. First, how does the coach start to identify and challenge factors that serve to maintain the status quo and generate organisational inertia, without disrupting team cohesion (i.e., team performance)? Second, what positionality will the coach adopt, and subsequently, what type of relationships will be developed with athletes as they navigate hierarchical team structures and rigid processes that inhibit alternative performance preparation methods? Third, what technological tools could support the process of evolving collective performance behaviours? Deciding how to address these key challenges required continual individual and group reflection, discussions with the players and wider coaching team, and a continuous process of engaging with scientific literature. The latter provided an important point of academic insight to guide self-reflection and critical thought and, therefore, better equipped MR to challenge accepted and normalised ways of performing.

Woods et al.'s (16) alignment of transdisciplinary research for sports science research and practice was adapted to (re)position my role, intentions, and interactions with the wider team. Quite quickly, based on hierarchical thinking and siloed practice, I realised that adopting a coach-led approach would not engage this group of players to embrace alternative ways of performing. I was concerned that they would become too reliant on me to solve performance problems and instruct them on what to do during competition. Deciding on how I would position myself within the wider team (athletes and the extended support staff group including the Head Coach, sport scientists, and performance analyst) was essential to change playing methods established within the sport for many years. Adopting a transdisciplinary approach (e.g., the framing of a competitive performance problem or challenge through the consideration and integration of fundamental principles), the wider team was encouraged to temporarily park their preconceived ideas about what it means to perform and collaborate to consider new opportunities (framed by collective principles to support competitive performance) aimed at surpassing current levels of performance. Adopting this view of integrating principles of performance reduced the effects on professionals working in disciplinary silos and placed a collective inquiry focused on the heart of the programme. This integrative approach was crucial to supporting a heterarchy of practice where all members of the wider team were given equal standing irrespective of playing experience or time spent as a practitioner. This contemporary approach supported the implementation of a transdisciplinary focus to integrate efforts confronting the problems and challenges that were likely to face the team in competition.

Initially, players were reluctant to contribute their ideas and challenge norms; after all, they would be challenging the very people responsible for their selection into the final World Cup squad. Therefore, although this power balance was never neutral, over time, players did start to offer their insights to evolve playing strategies. A pitfall of this approach was that the stronger (more confident) characters within the playing group tended to dominate conversations in group messaging chats and during team meetings specifically aimed at idea sharing. At certain points across the programme, these players were asked not to contribute in group settings but share ideas directly with the coaches away from shared forums. This approach also meant that these players became more confident in challenging me and other staff to highlight areas of contention. At first, I felt uncomfortable with this and assumed that I had a more informed perspective. However, as one player pointed out to me, their current experiences of the sport present a different perspective to mine, and just because his view did not align with my thinking does not signify that it has no value. This player–coach interaction highlights the dynamic nature of sport (and therefore the need for adaptability), where rules, physiological demands, tactics, and skill requirements can evolve and change from season to season. This means that a coach's perspective of a sport they played several years ago might be very different to a player's present-day experience.

This interaction is one example of the challenges experienced by the wider team when developing a reciprocal and collaborative relationship. Over time, this approach did open new areas of inquiry that could be explored together, contributing to the evolution of team performance (i.e., enhancing team synergy formation to coordinate efforts). To exemplify, during a team performance analysis session, a player highlighted his frustrations with playing across a balance of self-organising tendencies. He argued that team synergies during attacking phases were not as effective as playing under global influences (a structured game plan), raising concerns over losing momentum during the attacking phases of play. This point is highlighted here:

> At full pace (playing under global influences), and the times we did score is when we offloaded because we had support, then we were an actual threat because we've got power and we've got momentum that we can use, and we lost a lot of momentum (playing under local influences). If you go back through a lot of the sets, we did I don't know three out of five tackles we lost momentum because we either did a shit pass to someone who was at a stop, and he didn't really go any further, or we settled down or we decided to keep it (play safe). (Player 10, Interview data)

TABLE 2 Play the ball speed for global-to-local and local-to-global tendencies.

| | Tendency | |
|---|---|---|
| | Global-to-local | Local-to-global |
| PTB speed (s) | | |
| 0–2 | 7.35% | 11.27% |
| | (15) | (23) |
| 2–3 | 15.69% | 14.71% |
| | (32) | (30) |
| 3–4 | 13.73% | 12.26% |
| | (28) | (25) |
| 4–5 | 8.33% | 3.92% |
| | (17) | (8) |
| 5–6 | 1.96% | 2.45% |
| | (4) | (5) |
| 6+ | 5.88% | 2.94% |
| | (12) | (6) |

Total actions = 204, and data are reported as absolute frequencies and relative frequencies.

This interaction is just one example of where notational analysis data were used to open up further communication channels between the wider coaching team and the playing group. The players' qualitative insights and notational analysis data (**Table 2**) were used to frame a discussion that explored ways to evolve collective team attacking strategies. Based on the idea of momentum (identified by player 10), **Table 2** indicates attacking tendency and play the ball speed, which is considered an important part of gaining momentum in rugby league (41).

Whilst play the ball speed of 0–2 s could be considered the most effective way to perturb defensive stability to gain attacking momentum, this attacking indicator did not occur frequently (local-to-global 11.27%; global-to-local 7.35%). The most common play the ball speed was between 0 and 4 s under both self-organising tendencies. Alongside these objective insights, the qualitative insights of the playing groups were drawn upon identifying key properties related to enhancing play the ball speed. Following this interaction, the players were tasked with identifying factors that led to the team losing momentum (factors that notational analysis did not provide). Players collated these responses and presented them back to the wider group during a team meeting. As discussed next, these key properties provide practice designs aimed at enhancing team synergies.

## Enhancing team synergies within the athlete–coach learning system

Following an agreement between playing and coaching staff regarding match play and practice conditions encouraging exploration through elaborating flexible principles of play, I was faced with the challenge of designing practice conditions to facilitate the exploration of self-organisation tendencies through a heterarchy of bi-directional tendencies. Observations and reflections of practice that aimed to exploit bi-directional tendencies indicated that some players remained dependent on the certainty of having a very prescriptive way of playing. The collective team behaviour within these practices could be categorised as non-cooperative, revealing poor inter-player connectivity. I was surprised at how dependent some players had become on global influences (prescriptive instructions, verbal feedback, and detailed pre-determined performance plan), which made the challenge of integrating the two self-organising tendencies a difficult one. How could the coaching team start to break this dependency? What practice methods could be designed to encourage players to coordinate and regulate actions at a local level? An obvious starting point was aligning practice to the co-created principles of play by *guiding their intentions* (42). This approach could provide players with opportunities to use their unique capacities to explore adaptable and innovative performance solutions. However, practice that aligned with the principles of play encouraged the more dominant and confident players to act as a global influence on collective team actions. During practice, these players instructed, commanded, and directed their peers to carry out specific actions to achieve certain task goals. Although the coaching team encouraged a more flexible approach to exploring the principles of play, other influences (i.e., dominant players) meant that the balance between bi-directional tendencies was still dominated by global levels of influence. The potential for synergy formation to emerge from transactions between all the players in the squad was still inhibited. At this stage, identifying how to design practice conditions to exploit both bi-directional tendencies felt like an impossible task.

To improve the players' capability to adapt to bi-directional tendencies, it was important to delve into the applied scientific literature on networking in team sports. Orth et al.'s (43) conceptualisation of an *athlete–coach learning system* provided a framework to form co-adaptive relationships with the players. The framework proposes that a reciprocal and co-adaptive relationship is formed with the coach, athlete, and performance context, constituting a *learning system*. In this system, the coach and athlete continually collaborate to form couplings from which information emerges to facilitate *in situ* task constraint manipulation. Through this approach, new opportunities for skilled action, learning, and functional performance can form. Orth et al.'s (43) conceptualisation guided my thinking and actions, acknowledging that the learning process and any changes to the current pedagogical methods needed to be based on a mutually reciprocal co-adaptive relationship between the players and the coaching team. In other words, the process of learning and change was mutually dependent, in that it could not emerge in isolation because any changes within the learning system were based on interactions between the players and the coaching team. Crucially, the coaching team's use of notational analysis data and players' qualitative insights of playing under local influences highlighted the performance benefits of exploiting bi-directional tendencies (integrating top–down and bottom–up influences).

To exemplify, **Table 3** presents the summary data to indicate the number of defenders tackling the ball carrier and the levels of defensive stability at the point the tackle was made. Tackles made by one defender (global-to-local, $n = 81$; local-to-global, $n = 48$)

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TABLE 3 Attack and defensive outcome for global-to-local and local-to-global tendencies.

| | Tendency | | | | | |
|---|---|---|---|---|---|---|
| | Global-to-local | Local-to-global | Global-to-local | Local-to-global | Global-to-local | Local-to-global |
| | Defensive outcome | | | | | |
| | Great instability | | Moderate instability | | Stable | |
| Attack outcome | | | | | | |
| Tackled by one defender | 0.49% (1) | 0.98% (2) | 9.80% (20) | 12.25% (25) | 29.41% (60) | 20.10% (41) |
| Tackled by two defenders | 0% (0) | 0.49% (1) | 6.86% (14) | 7.84 (16) | 6.37% (13) | 4.90% (10) |
| Tackled by three defenders | 0% (0) | 0% (0) | 0% (0) | 0.49% (1) | 0% (0) | 0% (0) |

Total actions = 204, and data are reported as absolute frequencies and relative frequencies.

led to more stable defensive outcomes ($n = 101$), compared with moderate instability ($n = 45$) and greater instability ($n = 3$). Tackles made by two defenders had equal distribution between both tendencies ($n = 27$), leading to more moderate instabilities (local-to-global, $n = 16$; global-to-local, $n = 14$) compared with stable outcomes (global-to-local, $n = 13$; local-to-global, $n = 10$).

The use of data helped shift players' intentions, with greater value and meaning being placed on a more flexible way of playing (emphasising bottom–up influences a little more). Co-adaptive and tightly coupled interactions started to emerge through carefully considered constraint manipulations, based on emergent information emanating from the athlete–coach learning system (43). Here, the wider team collectively searched for, discovered, and manipulated constraints specific to the needs of individual and team behaviour.

Over time, this approach removed opportunities for dominant players to act as a global influence (because of the fast-paced and multi-dimensional practice conditions). Coaches and support staff encourage stronger local interactions in all players through collectively solving in-game performance challenges to facilitate more even bi-directional synergy formations. This meant that these dynamically changing practice tasks did not look like the game played in competition but required players to quickly adapt their collective behaviours to satisfy interacting individual and task constraints that were co-designed. During this phase of performance preparation, the team transitioned along a continuum of generality (variable practice conditions) (**Figure 1**) and specificity (representative practice conditions) (**Figure 2**) of practice conditions. This intentional pedagogical strategy aimed to break the dominant global tendencies and encourage a move towards bi-directional self-organising tendencies.

The combination of general and specific practice tasks facilitated players' exploration across different performance contexts, where players were observed becoming more responsive to opportunities for interaction, collaboration, and collective team play. The data presented in **Table 4** were shared with the players to demonstrate how effective collective play had become in perturbing defensive stability at the point of the tackle and the subsequent defensive stability when the play the ball occurs.

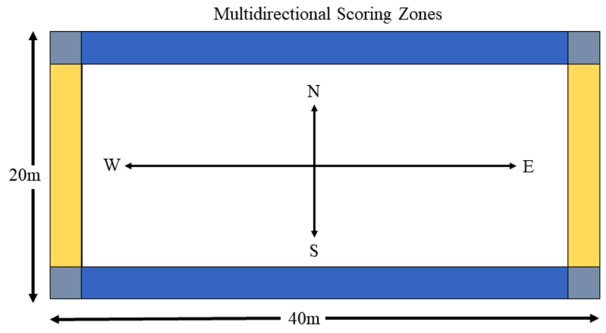


FIGURE 1
Two teams of 5 vs. 5 play against each other. Team 1's direction of play is north to south, scoring in the blue zones. Team 2's direction of play is east to west, scoring in yellow zones. Other than the normal game rules, no instructions are provided to the players. On the coach's signal (long whistle blast), teams change the direction of play and therefore the scoring zones. The game requires collective team (re)organisation to facilitate fast and multi-dimensional transitions to maintain defensive and offensive advantages, encouraging self-organisation at a local level.

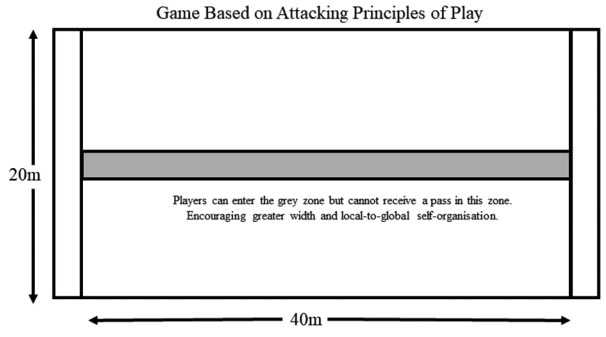


FIGURE 2
Two teams of 5 vs. 5 play against each other on a standard court, and normal international rules apply. Play is encouraged to practice based on the co-created principles of play [e.g., work in pairs, explore, vary play to play (early pass, change of direction, and tempo); all players stay alive on every play]. Depending on the period and focus of preparation, rules may be included that result in the attacking team maintaining or losing possession if principles are not applied. As indicated in the figure, pitch markings can be added to shape collective team behaviours relevant to the principles of play.

TABLE 4 Defensive stability at PTB and defensive outcome for global-to-local and local-to-global tendencies.

| | Tendency | | | | | |
|---|---|---|---|---|---|---|
| | Global-to-local | Local-to-global | Global-to-local | Local-to-global | Global-to-local | Local-to-global |
| | Defensive outcome | | | | | |
| | Great instability | | Moderate instability | | Stable | |
| Defensive stability at PTB | | | | | | |
| Great instability | 0.49% (0) | 0.49% (1) | 0% (0) | 0.49% (1) | 0% (0) | 0% (0) |
| Moderate instability | 0.49% (1) | 0.49% (1) | 8.33% (17) | 10.78% (22) | 3.43% (7) | 3.92% (8) |
| Stable | 0% (0) | 0.49% (1) | 8.33% (17) | 9.31% (19) | 32.35% (66) | 21.08% (43) |

Total actions = 204, and data are reported as absolute frequencies and relative frequencies.

## Players' perceptions of local-to-global self-organising tendencies

Drawing on players' experiences of performing under localised co-adaptive influences was crucial to developing a better understanding of the application and interplay of bi-directional tendencies. The perceptions of players also highlighted that high levels of physical and mental capacities are required to support effective engagement with this approach, offering important insights for the wider coaching team. It is important to note that performing when guided by a balance of local and global tendencies is termed *GFWS*. This was a principle of play identified by the wider team to encourage better team synergies. Therefore, throughout the next section, local-to-global tendencies are referred to as GFWS.

## Positive experiences

In general, players had positive experiences of GFWS, suggesting that it provided them with more "freedom" (meaning that they perceived that their decision-making and actions were not over-constrained by a rigid game model) to play, helping some players to improve their overall performance. Discussed here by one participant who discussed moving away from a "methodical" way of playing gave players' more autonomy to play a "free-flowing" style:

> Like back when I first started playing people like xxx (player) and xxxxx (player), they wouldn't have been as good as they are now if they didn't have the freedom because back in the day like they didn't have that freedom. Like it was very methodical, if that makes sense, whereas now it's like throw ball about and see what we can pull off. So yeah, it (GFWS) really opened my eyes up to like having that free-flowing rugby. (P9)

Importantly, participants also reported improved feelings of enjoyment and "confidence" from playing under GFWS. Player 2 also suggested that this way of playing improved the collective attacking ability of the team. He explains:

> Yeah, so go forward with support is an easy one to answer for me. I love it. I think it's brilliant. It's the way the game used to be played and I think it's very evident that coming back to that was a good idea. I think our attack look significantly better since we've began to correctly implement it and I'm a big fan. I think it's just a real basic way of playing that brings everyone down to just playing with confidence and enjoying it. (P2)

Participants' experiences of game-based practice sessions and competition highlighted their perception that defending against GFWS was difficult for opposition teams. This contributed to better *buy in* from the players when experiencing more effective attacking team play. A player explains:

> It's just so difficult to defend and even like the help D (a defensive strategy to implement during periods of instability) it feels a little bit like it's been designed to defend against go forward with support but even that can't properly always defend against it, and it doesn't require like brilliance or anything. It just requires going forward quickly and there's going to be gaps. (P4)

Players acknowledged that GFWS had superseded more structured elements of attacking phases of play. Importantly, there was a recognition that although GFWS was beneficial to game play, more global influences (structured play) were still important to smooth out periods of instability. Discussed here by player 6:

> Like that flamboyancy has like taken over like the structure and the structures good and like certain parts of the game where you know we're under the cosh, so you play out your sets and you complete your sets then you get back into the game. But yeah, it's completely opened my eyes to a different side of rugby. (P6)

## "We miss a lot of opportunities to attack"

Although the players report positive experiences with GFWS, they did raise concerns over missing opportunities to attack

under this approach. More specifically, when the team was in possession and aiming to advance the ball up field, they felt that the chaotic nature of GFWS meant that opportunities to attack space or exploit numerical advantages (e.g., two attackers vs. one defender) were missed. Highlighted here by player 5:

> We miss a lot of opportunities to attack because of the go forward with support, because like you said we have the overlaps on the right but then when we go two people left because it's like everyone is excited to go and they go left, and we've missed the opportunity. (P5)

When playing under GFWS, a principle developed by players and coaching staff was to support the ball carrier with at least one support player, and pass early, before contact is made with a defender. The early pass was aimed at changing the point of attack and creating further opportunities to advance the ball up field. However, as one player identified, this meant that although principles were being applied, sometimes players were too concerned about passing the ball even though it removed the attacking threat. He explains:

> We went up together with support, we were doing this, avoid a tackle and then offload it to someone that was right next to us, catch the ball, wouldn't have much speed so he's not really a threat. He would keep trying and then pass it again and it would just be constantly passing, passing, passing. (P7)

Players identified that they needed to "quickly recognise" the full range of opportunities for action during game play to enhance collective team attacking play. As one player discussed, adaptability was crucial to becoming better attuned to these opportunities:

> As players we need to recognise what's going wrong and like sort of change, not change the way we play, but quickly recognise what we need to do. (P6)

## A physical and mental challenge

A consequence of playing under GFWS was that physical and mental requirements were heightened. Players reported having to be "switched on all the time" when in possession of the ball because of the necessity to be involved with every play (carrying the ball, supporting the ball carrier, or setting up for the next play). Player 9 discusses this point:

> Like you have to be switched on all the time whereas before we'd be like resting on our laurels and go well it's the third tackle, we're just over the halfway line, we'll set one up at four (a specific point on the field) and then we'll run a set play or whatever. Do you know what I mean? So, it's a lot tougher like physically and mentally because you've got to be switched on all the time, but the results are speaking for themselves aren't they. (P9)

Player 8 also discusses this point, explaining that attacking play is so "rapid," highlighting that the selection for interactions between teammates and opposition players and further opportunities for action during practice and competition are a challenge:

> Well making decisions a lot quicker now. So, it's got to be a lot quicker, everybody's got to know and like you've got to see it, see what's happening, make the decision, let everybody know, like all in the space of like I don't know like five seconds. Not even that because of how quick the play of the ball is. It's so like rapid. So, I'd say it's changed it quite a lot because people like me, xxx (player), xxx (player) who play and make the decisions on the pitch are having to make it a lot quicker. (P8)

## Enhanced team synergy

The emphasis on localised influences on synergy formation during practice provided players with opportunities to collectively explore emergent self-organising tendencies. Players reported that performing under these constraints supported more effective interactions with each other, leading to enhanced team synergies. Discussed here:

> Yeah, definitely because it's not like one person in charge because everyone's on the same page and there's no sort of calls to be made. Everyone's then running sort of how they'd run, and because we're all doing it so frequently, we're getting used to each other and knowing when to go (carry the ball or support the ball carrier). (P2)

The comments of the players also suggested that new team synergies (coordination tendencies) emerged under GFWS, where players became more attuned to each other's future actions. For instance, this player discusses how a reciprocal understanding has been developed between teammates' intentions through the skill of offloading (passing during contact):

> I definitely feel with some players, really changed my interactions as in I know when I'm looking for an offload, I know they'll be there, or I know they'll be looking for an offload whereas before I didn't think of it that way. So, I've changed my interactions with them because I think I understand what they're trying to do on the pitch better. (P10)

It was also highlighted that coordination tendencies were heightened through more awareness of teammate positioning to provide more effective support during attacking opportunities. Exemplified here:

> … yeah it definitely keeps you more engaged because you're not just looking like where should I be, where is my position? It's where can I be to help them and where can they be to help me, and it just ups that level of communication. (P4)

Player 2 also discussed the development of team synergies, where there was more flexibility to collectively explore performance solutions. The flexible nature of GFWS meant that players did not have to arrive at an exact point on the field in preparation for a set play but rather focused on seeking out opportunities to advance the ball up field:

> Rather than it being a clear-cut opportunity all the time (through a structured game plan) it's more of a sort of decision-making basis (collective interactions under GFWS), and I think because of that people are getting less aggy (annoyed) with each other during games. Which then makes everyone feel better and then they carry on and do it and then they'll take more risks. (P2)

This example also suggests that stronger team synergies developed the functionality of the team, manifesting through different behaviours (taking more risks), structures (GFWS), and collective intentions (attack space and support the ball carrier).

## Discussion

The overarching purpose of this study was to explore the challenge of knowledge transfer within a high-performance team sports setting for performance preparation. Specifically, the aim was to support players to exploit bi-directional self-organising (inter-individual coordination) tendencies to facilitate emergent attacking behaviours that were contextualised to performance environmental demands. Results from the study highlight several factors that need to be considered when aiming to exchange knowledge in dynamic performance sport settings and provide empirical insights into a bi-directional synergy formation approach in training and performance. First, although challenging, placing transdisciplinary practice at the heart of development and performance environments can facilitate collaboration, thus leading to effective knowledge exchange. Second, implementing new or different knowledge informed by science, or day-to-day actions more generally, is deeply entwined within and influenced by a wider complex system (44). Third, learning systems and knowledge exchange are more effective when key agents within those systems accept that the coach, athlete, and performance context can and should operate through a reciprocal and co-adaptive relationship. In addition, whilst caution is needed when interpreting the results, the qualitative and quantitative data suggest that the bi-directional approach prompts effective learning and performance, where players assumed greater responsibility by actively (re)defining principles of play underlying individual and team performance. This approach can provide players with an increased sense of meaning (they feel part of the process and understand it) in the sense that they recognise the importance of establishing open and flexible principles based on their teammates' evolving characteristics and the specificities of the context.

These findings highlight that the challenge of knowledge transfer is embedded within the ecology of a complex system, signalling the need for sports scientists and practitioners to reconceptualise the traditional view of knowledge transfer. Situated learning scholars have long argued that knowledge in the form of facts or concepts has little meaning without consideration for the context within which it is intended to be applied (45). For Barab and Roth (46), useful knowledge is an appreciation of and an interaction between facts and concepts and the situations in which they have value. This reconceptualisation of knowledge calls for the rejection "of concepts as self-contained entities and instead conceive of them as tools—tools that can be fully understood only through use" [(46), p. 3]. Therefore, in the sports forum, knowledge transfer should not be viewed as the transmission of "an objective truth" to be imparted on passive recipients but as a contextualised activity reciprocally constructed and shared through continuous functional interactions between athletes, scientists, practitioners, and the performance context. This transactional activity has been termed "correspondence" in the ecological literature (47). Through these situated and contextualised interactions, new performance concepts, ideas, and opportunities can be embedded and explored deep within the ecology of a performance environment. However, when dealing with the challenge of knowledge transfer in context-specific performance environments, institutionalised methods and entrenched beliefs can seem to emphasise an "anti-intellectual agenda," meaning that positive interactions and, therefore, knowledge creation and transfer can be difficult to achieve [(21), p. 5].

This means that the acceptance, interpretation, and sharing of scientific knowledge and new methods by athletes, coaching practitioners, and sports scientists are socially, culturally, historically, and politically defined. For instance, the cultural, historical, and political backdrop of the team sport of rugby league can shape an individual's attitude to performance and development, leading to the acceptance and reproduction of practices dominated by top–down methods. As Collins (48), Coupland (49), and Rothwell et al. (5) argued, hierarchal systems of control, role specification, and task repetition are attitudes embedded in rugby league's identity, properties that are synonymous with top–down approaches in sports. In complex system theorising, strong context-dependent identities can make the challenge of knowledge transfer difficult. Take the example of England Rugby (50), who have attempted to lower the legal tackle height during competition. Even though changes to the tackle height were based on empirical studies aimed at improving player safety through reduced concussion rates, applying this knowledge into practice has received well-documented backlash from athletes and practitioners (51). This situation highlights that the constitution of scientific knowledge has little meaning when attempts are made to apply it without consideration of context, people, and settings.

As the results highlighted, when individuals within the athlete–coach learning system are adaptive and flexible, more effective and meaningful relations can be fostered. Through these relations, the collective team was more willing to collaborate and share their lived experiences of bi-directional tendencies, opening opportunities for this concept to "*live in* its contextual richness" [(46), p. 3]. This reciprocal approach facilitated a continual coupling of key agents (individuals), content, and context, enabling application, refinement, and opportunities for applied practice to evolve. Crucially, this reciprocity sensitised the wider team to the current performance situation, influencing whether certain components and their function on the overall CAS needed manipulating [e.g. (52)]. In this sense, when an athlete–coach learning system is being challenged to co-adapt through exploring new concepts, a network of *collective affordances* can be generated to evolve individual and team capacities towards a particular task (53, 43). This is evident here with the collective aim of developing more effective attacking synergies (i.e., becoming more proficient at scoring tries). For example, the reciprocal nature of communication, feedback, and interactions highlighted performance issues (e.g., missing opportunities to attack/players recognising what they need to do) that elicited changes to practice. In addition, these meaningful interactions aided the identification of physical and mental development, areas that were acted upon to enhance individual and team performance.

Whilst we recognise that more in-depth analysis of performing under local influences is required, the performance analysis data opened new opportunities for the coaching team and players to collaborate to evolve attacking strategies. This approach is far removed from typical reports of how performance data are used in the coaching process, where athletes are viewed as "objects" and "audience" of the performance analysis process [(54), p. 473]. Athlete insights from Bampouras et al.'s [(54), p. 473/474] study of the in-practice application of performance analysis highlight this trend. An athlete commented:

> We were never given the option to say you want to do it or not (performance analysis), how do you think it is going? Is it beneficial towards us or not? We were never given that kind of control.

Manley and Williams (55) argued that employing technology in this way can lead to feelings of anxiety and performance fatigue amongst athletes, in addition to creating barriers to the exchange of knowledge in the athlete–coach–environment learning system [e.g. (56)]. Conversely, using the performance analysis process to inform discussion points, practice designs, and the evolution of principles of play can foster learning environments where exchanging knowledge between athletes and coaches is the norm [for an excellent applied example, see (57)]. This study used data to support coaches' and players' understanding of the value of moving along a continuum of global and local self-organising tendencies to create instabilities within the defensive system.

Crucially, the performance analysis process and subsequent data set strengthened interactions between the players, coaches, and contents and focused player intentions towards specifying information sources and periods of play that presented opportunities to attack. The performance analysis data could suggest that flexible principles of play provide players with opportunities to adapt and refine novel performance solutions, evident through the destabilisation of defensive team structures [e.g. (30)]. Therefore, principles of play pertaining to a game model could be used to potentiate the evolving characteristics of the players through continuous skill-based engagement with a rich landscape of affordances. It should be noted that principles of play are the beginning of pattern or synergy formation and through a flexible approach should encourage players to recreate a particular principle as they develop an increasingly functional fit with the performance environment (58). Individual and team coordination patterns are not pre-determined, re-wired, or mechanised. Rather, players need to continually search for and utilise specifying information to accomplish principles of play. Through practice, players must be given time and space to explore and understand principles and operationalise them without constant monitoring and feedback or through the prescription of mechanised and repetitive performance solutions.

A fundamental point to be outlined here is that a game model allows the wider coaching team and athletes to structure and organise their practices around a framework of intentions according to the development of specific principles of play that form a team's identity. This intentionality framework could play to collective strengths and minimise the effects of weaknesses. Therefore, the game model must always be available to guide the players' attention and collective intentions (42) during the performance preparation process. This could be predicated on coaches organising and structuring practice designs to develop intended performance outcomes, coherent with the fulfilment of principles of play for attacking and defending phases. In this sense, used as a guiding framework, the game model or tactical principles of play are never the problem. Rather, the problem lies in how coaching practitioners and sports scientists conceive and use them in a highly prescriptive way.

## Limitations and future directions

It is important to acknowledge that a small body of research indicates that some practitioners are already beginning to successfully transfer knowledge into applied settings (59, 57). These examples have emerged in both individual (e.g., paddle sports) and team sports (rugby union) contexts. Future research is needed to continue to establish how practitioners could achieve knowledge transfer in elite sport performance contexts. Studies of this nature would supplement the findings from the qualitative element of this paper to provide important insights for both academics and practitioners, as it seems that the goal of knowledge transfer remains problematic. More specifically, research could distinguish between "what" decisions are made and "how" decisions are implemented regarding the application of empirical knowledge (60). The "what" knowledge represents the empirical knowledge that will help underpin the design and implementation of alternative performance preparation practices. These studies can also outline "how" these practices are delivered by practitioners and experienced by athletes.

Employing qualitative research methods, such as observations, interviews, and case studies, can verify key agents' lived experiences of the athlete–coach–environment learning system. To clarify, we are not suggesting the formulation of another methodology but rather the identification of principles that can promote the discovery of new synergies, not only in the player and team performance sense but also amongst academics, practitioners, and athletes, to facilitate the better application of sports science research.

Whilst the performance analysis data from this study focused more on opening new opportunities for co-adaptation between the coaching team and players, further insights could be crucial to understanding the value of moving between bi-directional tendencies. This case study examined a match sample from four games. Future research could address the feasibility of transitioning between bi-directional tendencies from various team sports using short-term (<6 weeks) intervention designs. Examining multiple teams would enable researchers to conduct inferential statistical analysis to explore the findings of a population beyond a narrow sample. Moreover, this recommendation for inferential statistical analysis is pertinent for knowledge transfer, given that the differences between "global-to-local" and "local-to-global" tendencies in this study were minimal. It is important to acknowledge that the coaching period of each condition in this study was unbalanced, with players receiving more time in the "global-to-local" condition coaching because of previous coaching and cultural practices of the national team. This tendency to direct the majority of practice towards more "global-to-local tendencies" in forming synergetic relations between players in training could further prove an over-valuation of "global-to-local" tendencies in team sports.

## 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 humans were approved by the Sheffield Hallam Sport Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent for the publication of any potentially identifiable images or data included in this article was obtained from the individual(s).

## Author contributions

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

## 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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