CONSUMER'S BEHAVIOR BEYOND SELF-REPORT

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CONSUMER'S BEHAVIOR BEYOND SELF-REPORT

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EDITORIAL
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Editorial: Consumer's Behavior Beyond Self-Report

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Editorial on the Research Topic

Consumer's Behavior Beyond Self-Report

INTRODUCTION

Incorporating facial electromyography (fEMG), electrooculography (EOG), electroencephalography (EEG), electrodermal activity (EDA; also known as galvanic skin response), electrocardiography (ECG), and eye-tracking into scientifically valid experimental paradigms empower scientists to answer questions about how individuals perceive, manipulate, and use the information to complete a task (Bettiga et al.; Choi et al.; Hu and Shi; Kaneko et al.; Klichowski and Kroliczak; Kwon and Kim; Ounjai et al.; Wolf et al., 2018, 2019). Notably, the data obtained through the advanced techniques not only give valuable insights into one's attentional and perceptional processes or emotional arousal, but also reveal responses that consumers do not want or are not able to express, e.g., specific groups of consumers like patients suffering from mental disorders or children (Cherubino et al., 2019; Rojas et al.; Wolf and Ueda).

Popular data collection methods involve questionnaires, surveys, and interviews (i.e., self-report measures) to have an insight into consumers' decision-making process (e.g., product evaluation, willingness to purchase). The general acceptance, practicality, and low cost make self-reports popular; however, they are often described with issues of over- or underestimated recall (e.g., inaccurate memory), response bias, and the inability to capture consumers' unconscious reactions (Bell et al., 2018; Bettiga et al.; Yang et al.). It has been reported that prior studies regarding the discrimination between hedonic and utilitarian products are grounded on self-reported experiences, which assess conscious emotions that subjects can recognize and verbalize, but not unconscious feelings (i.e., happening without individual awareness) (Bettiga et al.). The work of Bettiga et al. presents physiological analyses and depicts consumers' unconscious affective reactions as powerful drivers of decision-making. In addition, the team provides an initial step toward using physiological data regarding the subjects' cardiac activity (ECG), respiratory activity, and electrodermal activity (EDA) to evaluate consumers' experience with new products. This contribution casts new light on the conventional discrimination between hedonic (linked to sensory satisfaction, pleasure, and excitement) and utilitarian products that are associated with more functional and practical benefits (Bettiga et al.).

Kaneko et al. also recognized changes in ECG and EDA as a reflection of emotional state during a food-tasting event. In addition, the research group used explicit and implicit measures (e.g., a modified willingness-to-take-home scale) to examine the effect of emotional state on the experience of a novel soup (traditional Japanese soup based on seaweed broth) vs. a familiar food product (vegetable soup). In this study, one group of participants faced a "positive emotion induction procedure" (i.e., a promise of a reward after tasting). In contrast, a modified Sing-a-Song Stress

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Test (which causes profound social stress) was used to induce a negative emotional state in the second group. In conclusion, both soups were experienced as equally pleasant in the positive emotion condition, while in the adverse emotion condition, the new product and the familiar soup were experienced as relatively unpleasant and relatively pleasant, respectively. Thus, presented findings show that emotional state affects food pleasantness differently for novel and familiar foods (Kaneko et al.). As for straightforward application, this work states that one should introduce a novel food when consumers are not stressed. Otherwise, it may negatively affect food pleasantness, with the negative effect remaining at least 1 week. Hence, a positive recommendation would be to let consumers taste a new product when they are in a positive mood (Kaneko et al.). Finally, an interesting note regarding electrodermal activity was made by Lajante et al. who reported that neuromarketing agencies often use smartwatches to insight individuals' arousal levels. However, his perspective article reveals important implications, that is, Lajante et al. underline that the evaluation of advertisements mainly relies not on arousal but pleasure. Therefore, special attention must be paid to the merits of the experimental method, where facial EMG might be more informative than electrodermal activity for measuring aesthetic emotions in advertising research (Lajante et al.).

In the last years, research efforts related to consumer science have used eye-tracking to elucidate individuals' visual processing of presented stimuli (Ounjai et al.; van der Laan et al., 2015; Wolf et al., 2018, 2019). Since consumers are usually not aware of the steps of simplifying their decision-making processes (i.e., ignoring some options and paying more attention to preferred alternatives), gaze behavior, where the slightest change in gaze allocation reflects a shift in information-prioritization, permits better identification of consumers' unconscious processes (Bialkova et al., 2020; Rojas et al.). For example, Ma et al. examined whether food packaging with a transparent window has more advantages in capturing consumer attention and determining consumers' willingness to purchase than packaging with a graphic window (at the same region and size of the package). With eye-tracking technology, the research group provided objective evidence on attentional capture of three different packaging types (kindly refer to **Figure 1A**). Also, the authors stated direct applications; for example, in order to design a visually attractive product that will enhance consumers' willingness to purchase, food manufacturers should consider the category of packed food (Ma et al.).

Implementing research findings can become standard practice not only in product development but in interior design as well (Spence, 2020). Interiors such as healthcare and children's environments have started actively adopting sensory design features based on scientific suggestions (Cox et al., 2004; Collier and Jakob, 2017; Cheng et al., 2019). However, similar information has not been available for retail design, even though retail settings often involve many sensory information channels, being an exciting environment for multi-sensory studies. Kwon and Kim provide information about what customers see in commercial stores (coffee shops) and what factors trigger their gaze (see **Figure 1B**). Through this work, the authors (1) suggest a methodological framework that encompasses qualitative as well as quantitative measures, (2) take a unique opportunity to discuss faced challenges, and (3) share implications for optimal use of eye-tracking technology in the discipline of interior design (Kwon and Kim).

The editors find it necessary to acknowledge that the scientific community primarily focused on experimental paradigms under controlled laboratory environments when the call for potential contributions was made. In order to raise the question as to whether real-life context experiments help explain consumers' decision-making strategy (i.e., beyond the experimental room), the editors addressed scientists who show interest in ecologically valid experiments. For example, the study conducted by Klichowski and Kroliczak presents unique findings regarding the most critical skill behind consumer behavior, which is the ability to assess whether a price after a discount is a real bargain. While there is an agreement that the left posterior parietal cortex (PPC) contributes to mental arithmetic, it is unknown if it is involved in calculations of sale prices. Therefore, the researchers examined the role of PPC in mental shopping calculations. Moreover, the group re-modeled their laboratory to resemble a shop and asked participants to calculate the product's price after discount. The findings of this study shed preliminary light on the topic of mental calculations in a natural setting (Klichowski and Kroliczak).

Concerning the context of a real market, Suomala presented a theoretical explanation of consumer behavior. His plausible framework of the Consumer Contextual Decision-Making Model concludes that, though the content of meaningfulness is different among individuals from different cultural backgrounds, the concept of meaningfulness is the most vital trigger of consumer choice. Moreover, he underlines that decision-making reflects subjective meaningfulness based on experiences rather than objective features of the physical world (Suomala). This suggests that the role of the consumer's mental system in a decision-making situation is to process given information successfully to achieve assigned or self-set goals. According to that, Yu et al. demonstrated that consumption could be biased by incidental mental status. Some consumers exhibit a great interest in symbolic products that highlight their values in the context of social status, intelligence, and lifestyle (i.e., to reconstruct their self-identity).

Interestingly, even subtle hints in advertisements might trigger a compensatory consumption (i.e., when individuals purchase a product, not for its functionality but its signaling value) (Yu et al.). Individuals' efforts to avoid the psychological discomfort of self-threats via such compensatory consumption can backfire with negative consequences (e.g., physical, financial, and psychological) and lead to long-term harm (Yu et al.). For instance, purchasing products that compensate for psychological deficits might drive consumers to spend money beyond their budget on products they usually would not buy or could not afford. Also, consuming food to regulate one's emotional distress might lead to the development of eating pathologies and obesity. Yang et al. reported that in comparison with healthy controls, patients with seasonal affective disorder (SAD) exhibit a higher frequency of hyperphagia (an increased desire for food), external

FIGURE 1 | Application of eye-tracking technology in product packaging **(A)**, design of commercial stores **(B)**, and detection of cognitive impairments among clinical populations **(C)**.

eating (eating in response to external cues, such as sight or smell of food), and emotional eating (eating for reasons other than hunger) (Yang et al.).

Yet, there is insufficient research in the clinical domain that examines the decision-making processes among consumers, who suffer from psychiatric and mood disorders (Wolf et al., 2021). Wolf and Ueda underline that consumer neuroscience (that enriches understanding of consumer psychology and behavior) and neuroeconomics (that refers to sensemaking of economic problems through the analysis of neural correlates of decision making) should be studied, among healthy controls and patients, who suffer from mental disorders. Prominently, Wolf and Ueda put forward the aspects of combining eye-tracking methodology and real-life decision-making paradigms to disclose valuable information regarding patient's behavior and identify gaze metrics (such as scan-path length, see: **Figure 1C**) as potential biomarkers to improve diagnostic precision.

CONCLUSIONS

The selection of contributions supports the statement that neurophysiological tools can highlight the mechanisms underpinned human behavior, and therefore lead to an

improved understanding of consumers' thoughts, intentions, and believes that accompany the decision-making situation (Bettiga et al.; Choi et al.; Hu and Shi; Kaneko et al.; Kwon and Kim; Ounjai et al.; Wolf et al., 2018, 2019). Particularly, data captured by eye-trackers give valuable insights into how a viewer determines the subjective hierarchy of provided information and undertakes the decision strategy (Choi et al.; Danner et al., 2016; Motoki et al., 2021; Wolf and Ueda). Moreover, since self-reported and psychophysiological measures are more complementary than mutually exclusive, neuroscientific tools can increase the precision of self-report measures and give a more solid background to formulate future psychological laws and contribute to the broader discussion about driving forces in consumer behavior (Hu and Shi; Lajante et al.). Indeed, the Research Topic comprises studies that represent data from a relatively small number of participants. Nevertheless, gathered scientific contributions should be considered an inspiration for future paradigms that will reveal information about individuals' behavior at the population level (amongst healthy and clinical populations) and provide more explicit applications for marketing strategies.

While ethical implications in consumer research need to be continuously perfected (Wolf and Ueda), the Topic Editors express their hopes that the results of future replicable and non-invasive experimental paradigms, which record a range of physiological and neuroscientific data, will (1) improve and inform marketing strategies, (2) provide new frameworks for the explanation of consumer behavior in real market contexts, and last but not least (3) significantly support the knowledge regarding cognitive deficits among clinical populations.

AUTHOR CONTRIBUTIONS

AW wrote the manuscript with valuable revision from KU. All authors contributed to the article and approved the submitted version.

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Symbolic Product Superiority in the Neural Salience of Compensatory Consumption Behavior

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To cope with self-threat being induced by personal setbacks in daily life, compensatory consumption, especially on symbolic product, has been found to do valuable help to resolve discrepancies between ideal and actual self-concept. Conforming to symbolic self-completion theory, the current study adopted event-related potentials to explore the objective information processing stages in self-concept-impaired status (the defeat group) on a neural level. The behavioral results replicated previous findings that the defeat group gained stronger purchase intention for symbolic products than utilitarian products. The electrophysiological data demonstrated that perceptual difficulties for products in preliminary stage (N1) were steady among conditions, and after that, information processing separation emerged. In contrast to the individuals with a draw experience, those with a defeat experience raised highly focused attention (P2) and eager expectation (N2) for products, especially for symbolic ones. Meanwhile, symbolic (vs. utilitarian) products also evoked a higher emotional arousal level and slowed the diminishment of involved attentional resource (late positive potential) at late cognitive processing stage. Taken together, the sequential integration of multiple neural indicators contributes to elucidating the processing stages of compensatory consumption behavior.

Keywords: compensatory consumption, event-related potentials, symbolic product, defeat, purchase intention

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INTRODUCTION

Reality often falls short of expectations in real life. Humans routinely experience a variety of personal setbacks manifesting as discrepancies between ideal and actual self-concepts (Mandel et al., 2017), including core aspects such as self-identity, authority, intelligence, and perception of affiliation (e.g., Dalton, 2008; Rucker and Galinsky, 2008; Loveland et al., 2010; Lee and Shrum, 2012). The setbacks might result in negative mental states and induce individual motivation to resolve those discrepancies (Tesser, 1988). As an important strategy for coping with self-threats, symbolic consumption can achieve symbolic significance (e.g., status manifestation, conception expression, and class approach) through certain consumption behaviors referred to as

compensatory consumption (Gronmo, 1988; Woodruffe-Burton, 1998; Rucker and Galinsky, 2008; Kim and Gal, 2014). As an effective tool to address psychological deficits, the forms of compensatory consumption include compulsive buying (Faber and O'Guinn, 1992), impulsive purchasing (Bayley and Nancarrow, 1998), conspicuous consumption (Roy Chaudhuri et al., 2011), and so forth. A critical shared feature is that consumers seek symbolic rather than utilitarian values from these products or services (Rucker, 2009).

The symbolic self-completion theory (Wicklund and Gollwitzer, 1981) may provide theoretical support for compensatory consumption behavior in which humans tend to cover up or make up for their deficiencies by certain self-symbolized behaviors. More specifically, self-concept may present on several dimensions owing to its complexity; hence, when information on one dimension fails to outline one's ideal self-image, an individual might seek support from alternative dimensions. One such support that is relatively easy to achieve is symbolic behaviors, among which symbolic product consumption is one of the most common. Compared with traditional utilitarian products, symbolic products are defined as a commodity form that manifests value-related information (Baudrillard, 2016) about its owner, such as wealth, status, habit, and tastes. Consumption behavior specific to symbolic products may play an important role in self-support as one's possessions are related to self-concept completion and improvement (e.g., Ahuvia, 2005; Oyserman, 2009; Shankar et al., 2009). That is, the possessions, although they are worldly items, can also integrate into the self and further lead self-concept development in a homogeneous direction. Therefore, individuals encountering self-threats commonly cope by repairing their imperfect selves by consuming and exhibiting products, in other words, compensatory consumption. For instance, buying limited-edition products might help in building a wealthy self-concept (Sivanathan and Pettit, 2010).

Empirical behavioral studies in the field of marketing proved this compensatory process. Dalton (2008) found that participants given preset poor performance feedback for an intelligence test preferred to choose products to increase their self-identity (e.g., tee-shirt with an alma mater's school badge) as well as gift cards from exclusive shops. The reason for these behaviors might be that their failure of the intelligence test induced self-threat, resulting in their consumption of identity-symbolized products to achieve self-worth. Pens were also popular gift options for participants with poor intelligence test performance as they are an intuitive symbol of intelligence (Wang and Wang, 2011). Other studies reported that participants who were told they ranked within the worst 10% in a simple examination tended to pay much more on luxuries or limited-edition collections than those ranking within the best 10%, implying that ranking-symbolized products positively affected their threatened self-concept (Sivanathan and Pettit, 2010). Similarly, products to improve interpersonal relationships received attention from individuals experiencing social exclusion (Mead et al., 2011).

Although previous research showed the ubiquity of the attraction of consumers with impaired self-concept to self-symbolized products, little is known about the underlying psychological processes. People are likely to exhibit behaviors that are inconsistent with their visceral reactions, because some response strategies, exemplified by social desirability bias (Fisher, 1993), might distort their self-reports or subjective ratings. Unlike those output stage data (Yoon et al., 2012), neurophysiological approach helps researchers to observe people's involuntary reactions without the interference from those strategies that are not expected in the study. Specifically, the current study used event-related potentials (ERPs) to intuitively measure consumer information processing. ERPs have a relatively high temporal accuracy and can be used to investigate neural activities independent of subjective reports (Amodio et al., 2004; Luck, 2005; Ma et al., 2012). A sequential integration of multiple neural indicators would also help to elucidate processing stages throughout a purchase decision in compensatory consumption behavior.

Accordingly, the current study explored the cognitive processes of symbolic or utilitarian products in self-concept-impaired consumers. The impaired status was initially induced by defeat in a multi-round game, followed by a willing-to-buy rating task on symbolic and utilitarian products. Behaviorally, the willing-to-buy task was used to measure purchase intention, while neurologically, we used N1, P2, N2, and late positive potential (LPP) as ERP indicators during information processing.

As a critical component during early perceptual processing, N1 peaked approximately 130–150 ms after stimulus onset, reflecting the individual's perceptual difficulty with the stimuli (Wang et al., 2018). The following P2, with a peak latency at 100–200 ms after stimulus onset, is sensitive to attentional resource allocation (e.g., Carretié et al., 2001; Huang and Luo, 2006; Jin et al., 2017). Taking emotional stimuli as an example, a study confirmed that P2 amplitude was larger in response to negative stimuli (vs. positive stimuli) that evolutionarily increase the engagement of attentional resources (Carretié et al., 2001). This cognitive function of P2 might contribute to the relationship between purchase intention and variation in attention involvement. The anterior N2 component has also been used to investigate the role of conflict detection (Folstein and Van Petten, 2008; Ma et al., 2010; Liu et al., 2014; Jin et al., 2017; Jing et al., 2019). A mismatch between actual and expected stimulus elicits an N2 component at 200–350 ms, implying cognitive control in decision-making processes. In the late cognitive stages, LPP is an effective indicator of motivation and emotional arousal, occurring 300–500 ms after stimulus onset and lasting hundreds of milliseconds (Nieuwenhuis et al., 2005; Liu et al., 2014; Jin et al., 2017; Jing et al., 2019). As in the marketing literature, LPP amplitude was positively correlated with sustaining attention involvement and purchasing motivation (Ma et al., 2018).

On the basis of the above, we initially speculated that individuals with impaired self-concept would show a stronger subjective purchase intention for symbolic products compared with utilitarian ones, in addition to an analogical performance on a neural level. Neuroscientific techniques allow measurement

of underlying psychological stages reflecting the stages of consumer's decision-making process including perceptual difficulty, early and sustained attention distribution, perceptual conflict, and implicit consuming motivation.

MATERIALS AND METHODS

Participants

Thirty-four graduate and undergraduate students (18 females) with a mean age of 19.94 years (range: 1924 years, *SD* = 1.43) were paid to participate in this experiment. Half of the participants were enrolled in the defeat group (with a defeat experience in the experiment) and the other half in the draw group (with a draw experience in the experiment). All participants had normal or corrected-to-normal vision and provided informed consent before the experiment in compliance with the principles of the Declaration of Helsinki.

Stimuli

Two types of stimuli were adopted in the experiment. In the time estimation game, we used a 3.0° × 3.0° white square, always positioned in the center of the screen.

The target stimuli consisted of 80 product images, half of which were generally symbolic products, and the other half were generally utilitarian products. In the pretest, we used both behavioral and ERP experiments to ensure the homogeneity of all symbolic or utilitarian products images. The current study finally enrolled symbolic products, including pen, wine, and smart band, and utilitarian products, including ballpoint pen, beer, and clock, with 8–10 items for each type (see example product images in **Supplementary Material**). All product images were obtained from the Internet, and each measured approximately 5° × 7°, presenting on a gray background (RGB, 80, 80, 80).

Design and Procedure

Participants were seated in an electrically shielded and sound-attenuated recording chamber at a distance of 70 cm from a 19-inch CRT monitor (with a 100-Hz refresh rate). We used the E-Prime® software to control stimulus presentation and response acquisition. The procedures and study design were approved by the Research Ethics Board of the Academy of Neuroeconomics and Neuromanagement in Ningbo University.

The participants were provided clear instructions on performing the experimental trials. The experiment comprised two main tasks arranged sequentially, as illustrated in **Figure 1**.

Time-Estimation Game

The first part of the experiment was a time-estimation game (Yu et al., 2018). When the participants entered the laboratory, they were instructed to compete with participants as the opponents in

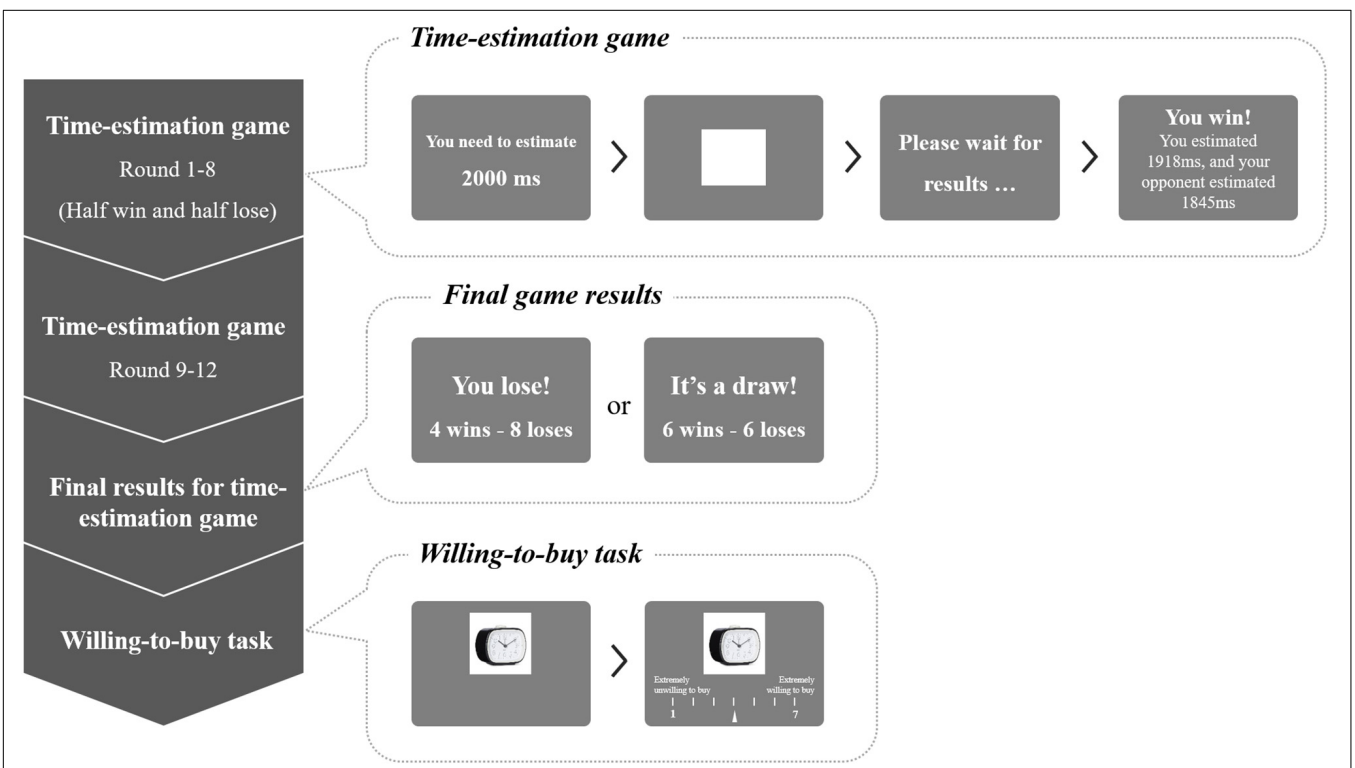

FIGURE 1 | Experimental procedure. The left diagram represents the general process; the top bubble on the right is an example of a round in time-estimation game with 2,000-ms estimation time in a win condition, proceeding from left to right; the middle bubble on the right presents the final results of 12-round time-estimation game; and the bottom bubble on the right is an example of a trial with a utilitarian product, proceeding from left to right.

a local area network (LAN)-based game. Their communication was restricted to a greeting when they first met at our laboratory. In the formal experiment, the LAN-based game was an offline game in which the opponent was one of the experimenters in disguise who did not play the game. These manipulations were used to control the participants' draw or defeat status. This time-estimation game required the participants to estimate an interval as accurately as possible with 12 total rounds. At the beginning of each round, an instruction was presented for 2,000 ms to indicate the interval that needed to be estimated, followed by a white square indicating the start of the game. The participants were instructed to press a button with their right index finger once they thought that the interval had elapsed. The square would then disappear and was replaced by a progress page instructing the participants to wait for the result, which lasted for 2,000–3,000 ms. Feedback was then given visually, informing the participants whether they had won or lost for this single round, along with the estimated times for both the participant and their opponent. This screen indicated the participants' actual estimated time, whereas the opponents' estimated time was conditionally controlled by the program. In the win round, the opponents' absolute value of the estimated time deviation was set to be larger than that of the participants (randomly generated from 50 to 400 ms), whereas in the lose round, the absolute value of the opponents' estimated time deviation was set to be smaller than that of the participants (randomly generated from 1 to 50 ms). The feedback information was presented for 5 s before the next round began. The interval between rounds was randomly determined from 2,000 to 2,500 ms.

For the first eight rounds, half of the rounds were manipulated as win and half of the rounds as lose, manifesting as a draw status in the first 2/3rd of the game. For the last four rounds, the participants in the draw group would experience two win and two lose rounds, whereas those in the defeat group continuously experienced four lose rounds. At the end of the game, the participant was shown the final game result (being defeated or getting a draw in all 12 rounds) and the numbers of win and lose rounds (4 wins and 8 loses for the defeat group and 6 wins and 6 loses for the draw group).

Willing-to-Buy Task

The second part of the experiment was a product willing-to-buy task. At the beginning of each trial, a product image was displayed in the screen center for 1,000 ms, followed by showing a 7-point Likert scale, from 1 (extremely unwilling to buy) to 7 (extremely willing to buy) with an initial pointer at 4. The participants were asked to rate their purchase intention for the displayed product by pressing the left or right buttons to move the pointer to the actual rating and pressing enter to confirm. Their final rating was recorded, with no time limitation for response. The 80 product images were randomly ordered. The task was divided into two blocks separated by a 5-min break.

After all trials had finished, participants were asked if they were aware of the experimental objective. No one answered affirmatively to these questions, and the data of these participants were then used for analysis.

Electrophysiological Recording and Analyses

Electroencephalogram (EEG) recordings were made at 64 scalp sites by using Ag/AgCl electrodes mounted on an elastic cap. The EEG and electrooculogram (EOG) signals were amplified by a SynAmps2 amplifier (Compumedics NeuroScan, Charlotte, NC, United States) with a sample rate of 500 Hz, using a 0.05- to 100-Hz band-pass filter. The left mastoid reference was used for all recordings, and the data were re-referenced for averaging the left and right mastoid voltages. Vertical EOGs were recorded by one pair of electrodes placed above and below the left eye, and horizontal EOGs were recorded by another pair of electrodes placed 10 mm at the outer canthus of both eyes. Impedances of all inter-electrodes were maintained below 5 kΩ during the experiment.

EEG data were analyzed using NeuroScan 4.3.1 and Curry 8. The initial processing for data was a correction for eye blinks by using a regression procedure. The EEGs were then filtered through a zero-phase shift with a low pass at 30 Hz (24 dB/octave), followed by segmenting into epochs ranging from 200 before to 1,000 ms after the onset of the product image for all conditions, and the epoch was baseline corrected using a 200-ms interval prior to the presentation of the product image. Trials with artifacts exceeding $\pm$ 100 μV in amplitude were rejected and excluded from analysis.

To assess N1, P2, and N2, electrode sites in the frontal (F1/Fz/F2) and centrofrontal (FC1/FCz/FC2) regions were selected for further analysis. We pooled electrode data for those two brain regions as a representative site because their patterns were similar. To assess LPP, we chose electrode sites in the centroparietal (CP1/CPz/CP2) and parietal (P1/Pz/P2) regions and pooled the two regions as representative of LPP for the same reason.

On the basis of the averaged waveforms in the present study as well as the results of previous studies, we defined the N1 and N2 peaks as the most negative point within 80–170 and 240–350 ms after product onset, respectively. The P2 peaks were defined as the most positive point within 150–220 ms. The LPP differences between subgroups occurred at 440 ms and lasted about 210 ms; thus, a time window of 440–650 ms after the product onset was used to measure the mean LPP amplitude.

One-sample *t*-tests were first used to examine participants' subjective purchase intention on products in each category, with a test value of 4 (the median rating in the 7-point Likert scale). With the use of the game result (defeat vs. draw) as the between-subject variable and product category (symbolic vs. utilitarian) as the within-subject variable, two-way repeated-measure analyses of variances (ANOVAs) were used to analyze purchase intention; amplitudes of product-onset N1, P2, and N2; and mean LPP amplitude during the time window of interest.

RESULTS

Behavioral Results

Only the rating for symbolic products in the defeat group exceeded the objective medium willing-to-buy rating; moreover, the subjective willing-to-buy ratings in both product categories in the defeat group were higher than those in the draw group (**Figure 2A**). Confirming this observation, one-sample *t*-tests revealed a significantly higher willing-to-buy rating for the symbolic product in the defeat group [M = 4.60, SE = 0.14, $t(16)$ = 4.11, p = 0.001], and, in contrast, a lower interest in the utilitarian product in the draw group [M = 3.47, SE = 0.15, $t(16)$ = -3.60, p = 0.002]. No significance was observed for the utilitarian product in the defeat group (M = 3.72, SE = 0.16, p = 0.09) or the symbolic product in the draw group (M = 3.93, SE = 0.16, p = 0.67).

The 2(game result) × 2(category) ANOVA showed the main effects of both game result [$F(1,32) = 5.44$, $p = 0.026$, $\eta_p^2 = 0.145$] and category [$F(1,32) = 54.0$, $p < 0.001$, $\eta_p^2 = 0.628$], in addition to the interaction between the two variables [$F(1,32) = 5.16$, $p = 0.03$, $\eta_p^2 = 0.139$]. The defeat group (M = 4.16, SE = 0.14) rated higher than the draw group (M = 3.70, SE = 0.14); moreover, symbolic products (M = 4.26, SE = 0.11) had a larger purchase intention than did utilitarian products (M = 3.59, SE = 0.11). Moreover, the increment from utilitarian to symbolic products was larger in the defeat group (d = 0.88) than that in the draw group (d = 0.46).

Event-Related Potential Results

N1

As shown in **Figures 2B,D**, the 2(game-result) × 2(category) ANOVA for N1 peak amplitude showed a marginally significant interaction between two variables [$F(1,32) = 3.60$, $p = 0.067$, $\eta_p^2 = 0.101$]. The increment of N1 (negative polarity: a smaller amplitude value indicates a higher N1 amplitude) from utilitarian to symbolic products tended to be smaller in the defeat group (d = -0.4) than that in the draw group (d = 1.03). No significant main effect was observed for game result [$F(1,32) = 0.55$, $p = 0.465$, $\eta_p^2 = 0.017$] or category, [$F(1,32) = 0.69$, $p = 0.411$, $\eta_p^2 = 0.021$].

P2

The P2 results are shown in **Figures 2B,E**. The 2(game-result) × 2(category) ANOVA for peak amplitude of P2 revealed a significant main effect of game result [$F(1,32) = 4.68$, $p = 0.038$, $\eta_p^2 = 0.128$] and an interaction effect between two variables [$F(1,32) = 10.63$, $p = 0.003$, $\eta_p^2 = 0.249$] in which the defeat group (M = 5.15, SE = 0.83) had a larger P2 amplitude than the draw group (M = 1.43, SE = 0.91), whereas the P2 increment (positive polarity: larger amplitude indicated increased P2 amplitude) from utilitarian to symbolic products was larger in the defeat group (d = 1.10) than in the draw group (d = -1.23). However, the main effect of category was not revealed [$F(1,32) = 0.03$, $p = 0.855$, $\eta_p^2 = 0.001$].

N2

The peak amplitudes of N2 showed similar patterns to those observed for N1 (**Figures 2B,F**). The 2(game-result) × 2(category) ANOVA for peak amplitude of N2 showed a significant interaction between two variables [$F(1,32) = 6.11$, $p = 0.019$, $\eta_p^2 = 0.160$], with a more negative N2 increment (negative polarity: more negative amplitude value indicated increased N2 amplitude) from utilitarian to symbolic products in the draw group (d = -1.24) than in the defeat group (d = 0.48). The main effects of game result [$F(1,32) = 1.59$, $p = 0.216$, $\eta_p^2 = 0.047$] and category [$F(1,32) = 1.15$, $p = 0.292$, $\eta_p^2 = 0.035$] were not statistically significant.

Late Positive Potential

The 2(game-result) × 2(category) ANOVA results for the mean LPP amplitudes at 440–650 ms (**Figures 2C,G**) indicated that the defeat group showed a larger amplitude (M = 8.94, SE = 0.80) than the draw group (M = 5.41, SE = 0.80) [$F(1,32) = 9.84$, $p = 0.004$, $\eta_p^2 = 0.24$]. Meanwhile, the significant interaction between game result and category [$F(1,32) = 5.73$, $p = 0.023$, $\eta_p^2 = 0.152$] indicated that the LPP increment (positive polarity) from utilitarian to symbolic products was larger in the defeat group (d = 1.03) than in the draw group (d = -0.53). The main effect of category was not obvious [$F(1,32) = 0.59$, $p = 0.450$, $\eta_p^2 = 0.018$].

DISCUSSION

This study assessed purchase intention for symbolic products in participants with impaired self-concept and explored the underlying information processing stages in these participants. In line with previous studies, the behavioral results showed a higher purchase intention for participants in an incidental defeated status compared with that in participants with a draw status; furthermore, as anticipated, the effect was increased for symbolic products. At the neural level, the early-elicited N1s were similar among conditions. Two ERP components with positive polarity, P2, and LPP were higher in the defeat group than in the draw group; and P2, N2, and LPP showed separation between symbolic and utilitarian products, with as stronger changes in neural activity for symbolic products.

The behavioral results confirmed our hypothesis that defeat status increased purchase intention (vs. draw status), especially for symbolic products. On the basis of the symbolic self-completion theory and previous findings (e.g., Dalton, 2008; Sivanathan and Pettit, 2010; Wang and Wang, 2011), we inferred that defeat in the time-estimation task would induce self-doubt and a discrepancy between actual and ideal self-concepts. To effectively make up for this deficiency, individuals seek products with corresponding self-support values from alternative self-symbolizing behaviors (Wicklund and Gollwitzer, 1981), and a strong purchase intention for symbolic (vs. utilitarian) products emerges. In addition, the main effect of category replicates those previously reported (Elliott and Wattanasuwan, 1998), implying the overall existence of symbolic consumption behavior.

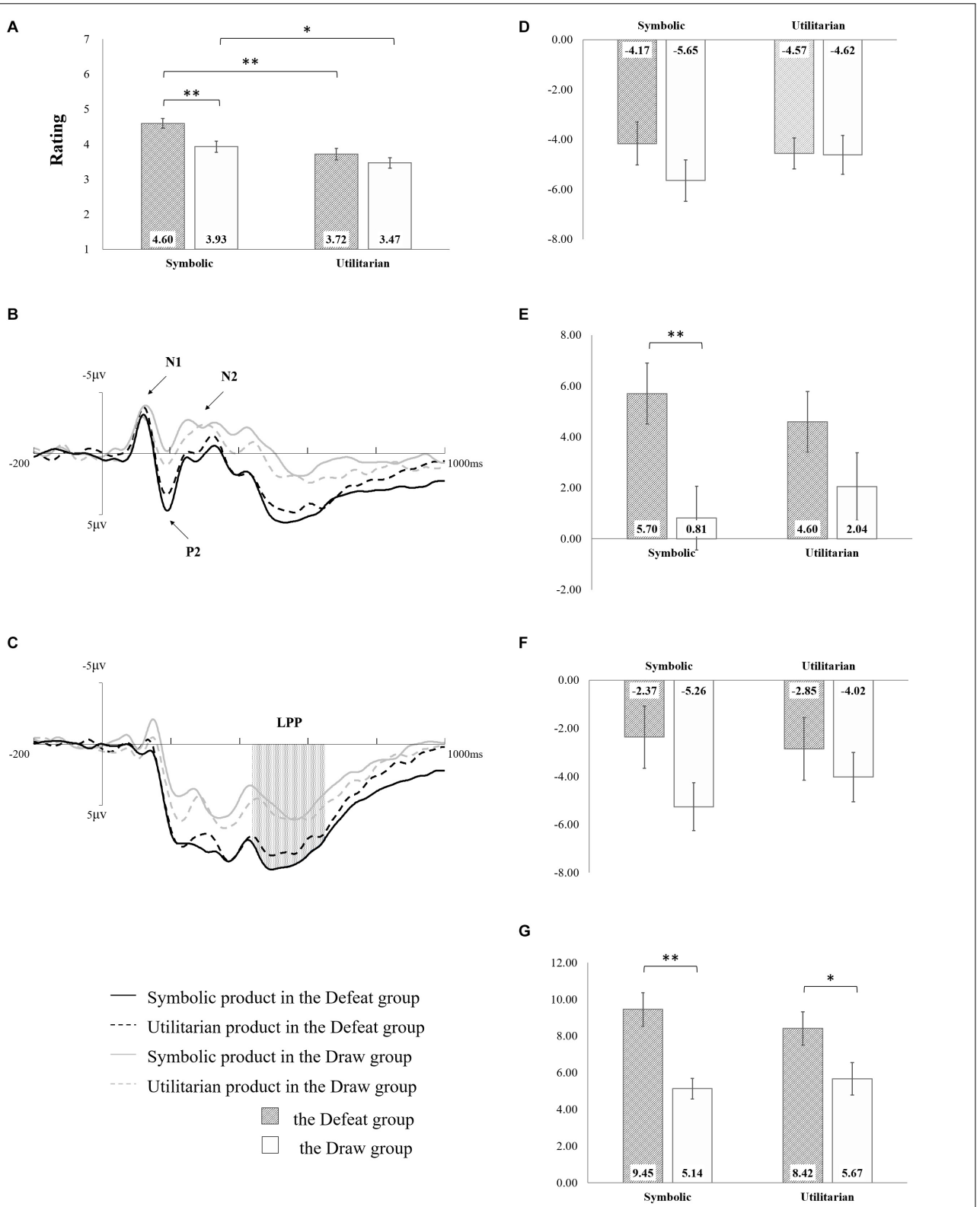

FIGURE 2 | Experiment results. **(A)** Behavioral results. **(B)** Averaged F1, F2, Fz, FC1, FC2, and FCz waveforms. **(C)** Averaged CP1, CP2, CPz, P1, P2, and Pz waveforms. **(D)** Mean peak N1 amplitude. **(E)** Peak mean P2 amplitude. **(F)** Mean peak N2 amplitude. **(G)** Mean late positive potential (LPP) amplitude. The asterisks represent significant differences (*$0.01 < p < 0.05$, **$p < 0.01$) between two corresponding conditions; the error bars represent one SEM; and the absent label between two conditions means non-significant difference.

The ERP results provided more concise interpretations of information processing in compensatory consumption. At the preliminary stage, N1 showed similar patterns for all product images, suggesting a stable perceptual difficulty in perceptual behavior control (Wang et al., 2018). In other words, regardless of competition outcome and product category, this factor was homogeneous for those products in the participants' evaluation of purchasing disadvantage, including perceptual emergency and purchase conveniences.

The following P2, as a robust reflection of attention involvement (Carretié et al., 2001; Huang and Luo, 2006; Jin et al., 2017), was higher in the defeat group than that in the draw group. The difference in P2 amplitude was most likely due to a highly concentrated allocation of attentional resources in individuals with impaired self-concept. According to product category, the draw group tended to show higher rational engagement with utilitarian attributes, but the situation changed for participants with impaired self-concept. The defeat group showed predominant attentional resource distribution for symbolic products; in other words, when the participants were defeated, they raised more concerns about symbolic attributes (vs. utilitarian attributes).

During mid-stage information processing, N2 is an index of the similarity between actual and expected stimuli (Ma et al., 2010). The interaction effect showed a more negative N2 for symbolic products compared with utilitarian products in the draw group, whereas the N2 amplitude was sharply decreased in the defeat group. A self-concept discrepancy may motivate a participant's need for self-support, which is the aim of symbolic products. The close similarity in symbolic attributes between the actual and expected products led to a relatively weak perceptual conflict in purchase intention evaluation.

Research in consumer psychology demonstrated a probable relationship between N2 and perceived risk because risk and conflict are interrelated (Folstein and Van Petten, 2008; Spapé et al., 2011; Larson et al., 2012; Ma et al., 2015; Wang et al., 2016). Compared with products with high review ratings, those with low ratings evoked greater perceived decision risk, resulting in a larger N2 amplitude. In the current study, the apparent symbolic attributes in symbolic products reduced the perceived risk; thus, the participants' inhibitions were weakened; more simply, they were more willing to make a purchase decision.

Concerning LPP in the late processing stage, the current study demonstrated both a significant main effect of game result and interaction between variables. An enhanced LPP within a time window of interest indicates a sustained involvement of cognitive resources and high emotional arousal on motivationally salient stimuli (Ma et al., 2018; Wang et al., 2018). Thus, the data from the present study suggested that defeat status (vs. draw) slowed the diminishment of involved attentional resources for displayed products; meanwhile, emotion arousal would be intense, implying a willingness to make purchase decisions on those products. This effect would be greater for symbolic products because their possession could improve the self-concept completeness.

Although the perceptual difficulty for products in the preliminary stages was constant among all conditions, three ERP deflections—P2, N2, and LPP—were modulated by the game results and product categories and showed similar patterns. Previous studies also reported the priority of symbolic products of various dimensions in self-concept-impaired situations (Dalton, 2008; Rucker, 2009); however, this is not the only influence on consumption behavior from the compensatory need. Current findings further revealed multi-stage cognitive processing for compensatory consumption behavior: high concern and eager anticipation for symbolic products increase to meet compensatory demand; in turn, those products help evoke higher emotional arousal and sustain attention, finally affecting the purchase intention.

The findings of the present study provide insight for sellers and demonstrate that consumption can be biased by incidental mental status. Along with the heavy life and social stresses, consumers are interested in symbolic products that highlight their personal values in the context of social status, intelligence, lifestyle, and so forth, because the possession of such products seems to be the easiest way for them to reconstruct their self-identity. Thus, subtle and moderate hints in advertisements to motivate a compensatory status might trigger consumer resonance. In coordination with an emphasis on its symbolic significance, consumers may pay increased attention to the product and further raise their purchase intention. In addition, the neuroscientific approach in current study theoretically contribute to revealing some detailed phases of cognitive processing underlying the external purchase preference on symbolic products in compensatory consumption, as well as avoiding the influences of confounding factors such as social desirability to a large extent. Furthermore, considering that the comparison between the defeat and draw groups in current study separated the game results from competition, the overall influence of the competition experience and results on subsequent consumption behaviors is also a rich topic in future studies.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Research Ethics Board of the Academy of Neuroeconomics and Neuromanagement in Ningbo University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

WY and ZS contributed to the conception and design of the study, performed the statistical analysis. ZH and CY performed the experiments. WY wrote the first draft of the manuscript.

QM reviewed and improved the manuscript. All authors read and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00838/full#supplementary-material

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More Proximal, More Willing to Purchase: The Mechanism for Variability in Consumers' Purchase Intention Toward Sincere vs. Exciting Brands

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Sincerity and excitement are core brand personality dimensions, which capture the majority of consumers' personality perceptions associated with brands. Previous research has demonstrated that consumers are more willing to purchase sincere brands than exciting brands. The present research addresses the mechanism underlying this variability. A total of four studies were conducted. Study 1 adopted survey-based design and manipulated brand personality by two versions of fictitious coffee brands. Results showed that sincere (vs. exciting) brands elicited more proximal psychological distance and in turn led to higher purchase intention. With a similar procedure, a different sample, and a different product (vacuum cup), Study 2 replicated the pattern demonstrated in Study 1. Moreover, the impact of brand personality upon psychological distance was found to be more prominent among consumers with high (vs. low) levels of attachment anxiety. Because psychological distance is proposed and proved to be a critical variable for mediating the variability in purchase intention, we adopted cognitive computerized tasks in Studies 3–4 to test whether stimuli perceived as sincere and exciting will induce different responses relevant to the perceptions of psychological distance. Study 3 adopted a picture-word version of Stroop task to test whether the automatic activation of personality-priming words would carry various perceptions of psychological distance, and results showed that participants classified distance faster when a close (vs. far) spatial distance matched sincere words and when a far (vs. close) spatial distance matched exciting words. Study 4 adopted the interference task to examine whether visual attention would be affected by personality-priming images, and results indicated a stronger cueing effect and an articulated interference effect for sincere (vs. exciting) figures. This research advances the literature of brand personality by probing the important role of psychological distance and further elaborating on the variability of consumer behavior toward sincere and exciting brands.

Keywords: brand personality, purchase intention, psychological distance, attachment anxiety, attachment avoidance

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INTRODUCTION

Consumers' perceptions of associating the personality traits with a product/brand and corresponding responses have been documented and examined in the consumer literature (Aaker, 1997; Fournier, 1998). Such symbolic associations that consumers develop and maintain through interactions with products/brands (Chen et al., 2015) are termed as brand personality. Brand personality represents "the set of human characteristics associated with a brand" (Aaker, 1997, p. 347). By personifying brands in this manner, consumers help create and sustain an intimate relationship with the brand (Fournier, 1994; Aaker, 1997). Considering this, marketing practitioners view brand personality as a strategic tool for brand differentiation (Park and John, 2012; Ha and Janda, 2014; Hultman et al., 2015) and a central driver of consumer preference (Guevremont and Grohmann, 2013; Gordan et al., 2016).

Similar to human personality, brand personality is composed of various dimensions (Aaker, 1997; Geuens et al., 2009). Of the five brand personality dimensions developed by Aaker (1997), which represents the most prominent operationalization of brand personality (Eisend and Stokburger-Sauer, 2013; Matzler et al., 2016), sincerity and excitement are considered as the two primary brand personality dimensions, because these two appear to capture the majority of the variance in personality ratings of brands (Aaker, 1997; Aaker et al., 2001), and they also constitute two of the three partner ideals in intimate personal relationships: warmth–trustworthiness and vitality–attractiveness, respectively (Fletcher et al., 1999; Aaker et al., 2004). Accumulating evidence has indicated that consumers are more willing to purchase sincere brands than exciting brands (see a review in Eisend and Stokburger-Sauer, 2013). However, the mechanism underlying this discrepancy across sincere and exciting brands has not been adequately investigated. Considering the prevalence of brand personality perceptions among consumers and the popularity of brand personality promotion strategy in marketing/advertising practices, it is critical to investigate this issue. We aim to address this gap in the present research.

Sincere brands are perceived as warm and down-to-earth (Buss, 1991; Robins et al., 2000; Aaker et al., 2004), whereas exciting brands as energetic and possessing vitality (Aaker et al., 2004). Sincere and exciting brand personalities primarily tap into agreeableness and extraversion of the "big five" human personality traits, respectively (Aaker, 1997). Social psychologists reveal that people are more likely to include individuals with high agreeableness (vs. extraversion) in their inner social circles (Wortman and Wood, 2011). Research in impression formation processes of individuals and groups has demonstrated that people attach more value to sincerity than to excitement (Leach et al., 2007; Brambilla et al., 2013). Moreover, it is indicated that perception of sincerity promotes relationship intimacy (Reis and Patrick, 1996). In marketing landscape, it was suggested that consumers' relationship with brands is stronger when the brands are perceived to be more sincere (Arya et al., 2019). Hence, sincere (vs. exciting) brands should be perceived as closer or more proximal by consumers.

A number of empirical studies have demonstrated that psychological distance of an object or a person from a perceiver is a key factor in determining his/her judgments of this object or this person (e.g., Harwood and Lin, 2000; Etang et al., 2011; Liberman and Trope, 2014; Thomsen et al., 2016). For instance, participants were more willing to give out money to people who were relatively more proximal toward them (Etang et al., 2011). Psychological closeness/distance constitutes a geographic metaphor used to describe personal experience, involving the abundance/absence of communication with one another (Kreilkamp, 1984). Within the marketing context, psychological distance between consumers and brands suggested the degree of connection or psychological bonds (Story and Hess, 2006; Trope et al., 2007). Recent studies revealed that manipulation of a proximal psychological distance could improve brand trustworthiness and online purchase behaviors, especially for the first purchase encounter with a previously unknown retailer (e.g., Edwards et al., 2009; Lii et al., 2013; Darke et al., 2016). These findings present evidence for the proposition that proximal psychological distance between consumers and a brand should promote consumers' positive evaluations or purchase intention toward the brand. Taken together, we hypothesize the following:

> H_1: Consumers' more willingness to purchase sincere (vs. exciting) brands is mediated by the more proximal psychological distance induced by sincere (vs. exciting) brands.

Furthermore, how consumers form relationship with brands should differ by individual characteristics. Considering empirical studies in social psychology indicating that interpersonal relationships are affected by individuals' attachment styles (e.g., Rom and Mikulincer, 2003; Wei et al., 2005; Levi-Belz and Lev-Ari, 2019), we adopt the attachment theory (Bowlby, 1980) to further elaborating on individual differences in the influence processes underlying consumers' purchases toward sincere vs. exciting brands.

In the attachment theory, two dimensions (i.e., attachment anxiety and attachment avoidance) are proposed based on individual's view of self and others, which are likely to determine the types of relationships he/she wants to engage in Bartholomew and Horowitz (1991); Collins and Stephen (1994), Pierce and John (1998) and Bartz and Lydon (2004). Individuals with high attachment anxiety are perpetually preoccupied with their self-worth and self-esteem concerns and direct excessive attention toward attachment figures by using a defensive strategy known as hyperactivation (Mikulincer et al., 2003). Hyperactivation implies greater vigilance of relationship-related behaviors and information. Individuals with high levels of attachment anxiety rely more on external sources to enhance self-worth (Mikulincer et al., 2003) and persist in seeking external comfort, reassurance, and support (Birnbaum et al., 2006). Given that sincerity (vs. excitement) meets more characteristics of an ideal partner for interpersonal relationships (Fletcher et al., 1999; Aaker et al., 2004), sincere brands should be perceived as more comforting and

reliable by consumers with high attachment anxiety than by consumers with low attachment anxiety. Therefore, it can be predicted that psychological distance between sincere brands and consumers should be more proximal for individuals with high attachment anxiety than for individuals with low attachment anxiety. Considering the foregoing discussion on the mediation effect of psychological distance on consumers' purchase preference of sincere over exciting brands, we hypothesize the following:

> H_2: Purchase preference of sincere over exciting brands is more prominent for consumers with high (vs. low) attachment anxiety, which occurs via the more proximal psychological distance of sincere brands toward the consumers.

Regarding attachment avoidance, individuals with high attachment avoidance are characterized by a high degree of self-reliance and desire for autonomy (Mikulincer et al., 2003). Avoidant individuals are reluctant to rely on others. Findings show that individuals with high attachment avoidance tend to have relationships characterized by low levels of emotional involvement and satisfaction (Hazan and Phillip, 1987; Collins and Stephen, 1994; Kirkpatrick and Davis, 1994). In contrast, individuals with low avoidance have a favorable view of others and are interested in pursuing intimate and close relationships (Hazan and Phillip, 1987). Therefore, it is likely a sincerity (vs. excitement) brand personality is perceived as closer toward these consumers given the more consistency with low avoidant consumers' expectations of brand partners. As thus, we predict the following:

> H_3: Purchase preference of sincere over exciting brands is more prominent for consumers with low (vs. high) attachment avoidance, which occurs via the more proximal psychological distance of sincere brands toward the consumers.

With four studies, we examined whether the more proximal distance perceived by consumers of sincere (vs. exciting) brand personality induces a higher level of purchase intention toward sincere (vs. exciting) brands (H_1) and, furthermore, whether the impact of brand personality on psychological distance varies across different levels of consumers' attachment anxiety (H_2), as well as attachment avoidance (H_3). Study 1 adopted survey-based design to test H_1. With a similar procedure and a different sample, Study 2 examined generalizability of the effect of brand personality demonstrated in Study 1 in another product category (vacuum cup) and meanwhile investigated the moderating role of consumers' attachment style in the impact of brand personality on psychological distance. Specifically, we investigated whether sincere (vs. exciting) brand personality is likely to be more proximal and more appealing to those with higher attachment anxiety or lower attachment avoidance.

Because psychological distance is proposed to be a critical variable for mediating the variability in purchase intention, we adopted cognitive computerized tasks in Studies 3 and 4 to test whether stimuli perceived as sincere and exciting will induce different responses relevant to the perceptions of psychological distance. Based on the assumption that people can automatically process and assess psychological distance of any target (Bar-Anan et al., 2006, 2007), Study 3 adopted a revised Stroop task to test whether the automatic activation of personality-priming words carry various perception of psychological distance. Study 4 adopted the interference task (Shen et al., 2016) to examine whether visual attention would be affected by personality-priming images.

STUDY 1

The core object of Study 1 was to test the basic prediction within the marketing context that sincere brands will induce a more proximal psychological distance than exciting brands, and psychological distance mediates the relationship between types of brand personality and purchase intention.

Materials and Methods

Stimuli Selection

We first designed two versions of a website for manipulating the brand personality of a fictitious coffee brand named CARLO. Note that we used a fictitious brand in this research for two reasons: (1) it allowed us to cleanly manipulate the brand personality, while controlling for the brand name across conditions; (2) it enabled us to test if the effect of brand personality on psychological distance and purchase intention was robust enough to emerge in the context of relatively unknown or new brands. We followed Aaker et al. (2004) detailed procedure to manipulate brand personality. Specifically, we varied four key elements of the website: color (soft brown vs. bright red), visuals (sitting dog vs. jumping dog), font (Comic Sans vs. Algerian), and content (family picnic vs. parachuting). Please see **Supplementary Appendix A** for stimuli.

A pretest ($n = 46$) was conducted to evaluate the effectiveness of the manipulation of the brand personality using a validated scale for brand personality (Aaker et al., 2004). Participants were asked to rate the degree to which each brand was perceived as associated with five measurement items for sincerity traits ("sincere," "honest," "wholesome," "down-to-earth," "family oriented"; 1 = not at all, 7 = to a great extent; $\alpha = 0.85$) and five measurement items for exciting traits ("exciting," "unique," "young," "imaginative," "daring"; $\alpha = 0.81$). Findings confirmed that participants presented with the sincere website rated CARLO as more sincere (mean = 4.74, $SD = 0.81$) than those presented with the exciting website (mean = 3.66, $SD = 0.57$), $F(1, 44) = 27.39$, $p < 0.001$, $\eta_p^2 = 0.38$. Similarly, participants presented with the exciting website rated CARLO as more exciting (mean = 4.72, $SD = 0.72$) than those presented with the sincere website (mean = 3.68, $SD = 0.64$), $F(1, 44) = 26.35$, $p < 0.001$, $\eta_p^2 = 0.38$. No significant group difference in ratings of other three brand personality dimensions (competence, sophistication, and ruggedness; Aaker, 1997) for CARLO were detected, P's > 0.10.

Participants and Procedure

Ninety-five undergraduate students (37 males, 58 females, $mean_{age}$ = 21.76 years, SD_{age} = 2.49) were recruited to participate in this study. Participants were randomly assigned to view a website page introducing a sincere or exciting brand. The website page for introducing CARLO appeared on a tablet in order to mimic our product search process when shopping online. They were informed with the following scenario: a new coffee product of this brand was being introduced by the company recently, and this study was commissioned on behalf of the company to gain feedback about the product. Participants were further asked to answer survey questions relevant to the presented product. In specific, purchase intention was captured on a two-item scale ("likely to purchase," "probable to purchase"; 1 = not at all, 7 = to a great extent; α = 0.81). Next, participants reported their perceived psychological distance of the brand from themselves on a three-item, seven-point scale adapted from previous research by Aron et al. (1992) and Liviatan et al. (2006) ("closely associated with the brand," "similar to users of the brand," "overlap of self and the brand"; α = 0.93). To control for the possible effect of the product familiarity and health concern on brand preference, product familiarity was measured on a two-item, seven-point scale ("frequently purchase coffee," "experienced in purchasing coffee"; α = 0.82), and health concern was measured on a single item ("I think coffee is harmful to health").

It should be noted that, as researchers suggested (Aaker et al., 2004; Sundar and Noseworthy, 2016), consumers see exciting brands as unorthodox and unpredictable and sincere brands as consistent and authentic. It can be predicted that consumers will be aroused more when seeing exciting brands than sincere brands. In order to test whether arousal may be a potential facilitator for purchase discrepancy across sincere and exciting brands, we also included the measurement of arousal here. Arousal was measured on a three-item, seven-point scale adapted from the previous research by Kaltcheva and Weitz (2006) ("This brand attracts my attention," "This brand arouses me," "This brand makes me feel exciting"; α = 0.90). We also collected a manipulation check for brand personality (discussed in the pretest). The instrument concluded with basic demographic information.

Upon completion, participants received financial rewards for their time. All of them provided written informed consent to participate in this study.

Results

Manipulation Check

Analyses of sincerity and excitement as a function of brand personality confirmed the effectiveness of the manipulation of brand personality, such that participants perceived the sincere brand to be more sincere (mean = 5.20, *SD* = 0.81) than the exciting brand (mean = 3.56, *SD* = 1.10), $F(1, 93) = 69.00$, $p < 0.001$, $\eta_p^2 = 0.43$. Similarly, participants perceived the exciting brand to be more exciting (mean = 5.00, *SD* = 1.00) than the sincere brand (mean = 3.64, *SD* = 0.87), $F(1, 93) = 50.12$, $p < 0.001$, $\eta_p^2 = 0.35$.

Hypothesis Testing

To explore whether psychological distance mediated the impact of brand personality on purchase intention, we ran mediation analyses following the procedures developed by Baron and Kenny (1986) (**Table 1**). First, we ran a regression analysis with purchase intention as the dependent variable, brand personality (1 = sincere; 0 = exciting) as the predictor, and product familiarity and health concern as covariates. Results revealed a significant main effect of brand personality (β = 0.39, $t = 3.93$, $p < 0.001$), indicating that participants were more willing to purchase a sincere brand (mean = 4.76, *SD* = 1.24) than an exciting brand (mean = 3.72, *SD* = 1.43).

Second, an analysis of psychological distance as a function of brand personality (1 = sincere; 0 = exciting), with covariates controlled, revealed a significant main effect of brand personality (β = 0.24, $t = 2.42$, $p = 0.01$), indicating that sincere brands were perceived as more proximal (mean = 3.16, *SD* = 1.58) than exciting brands (mean = 2.62, *SD* = 1.42).

When both brand personality and psychological distance were included in the model, the main effect of brand personality became weaker (β = 0.25, $t = 2.98$, $p < 0.01$), as compared to the effect of brand personality in the first model mentioned above (β = 0.39, $t = 3.93$, $p < 0.001$), whereas the effect of psychological distance was significant (β = 0.57, $t = 6.77$, $p < 0.001$). The results of the bootstrapped analysis (Model 4; Hayes, 2012) revealed a significant indirect effect of psychological distance [IE = 0.39, 95% confidence interval (CI) = 0.09–0.72, excluded zero]. These findings are consistent with H_1, which stated that psychological distance mediates the impact of brand personality (sincerity vs. excitement) on consumers' purchase intention.

We also tested whether arousal would be a potential mediator for the impact of brand personality. A regression analysis of arousal as the function of brand personality, with covariates controlled, revealed a marginally significant main effect of brand personality (β = −0.18, $t = -1.73$, $p = 0.09$), which indicated that the exciting brand tended to be perceived as more arousal (mean = 3.89, *SD* = 1.50) than the sincere brand (mean = 3.35, *SD* = 1.26). However, we conducted the similar bootstrapped mediation analysis (Model 4; Hayes, 2012) with arousal entered as the mediator, brand personality as the independent variable, and purchase intention as the dependent variable. Results showed that arousal did not mediate the relationship between types of brand

TABLE 1 | Results of the mediation analysis in Study 1.

	β	*T*	*P*
Step 1 (DV = purchase intention)			
Brand personality	0.385	3.926	<0.001
Step 2 (DV = psychological distance)			
Brand personality	0.242	2.424	0.01
Step 3 (DV = purchase intention)			
Brand personality	0.247	2.982	<0.01
Psychological distance	0.571	6.773	<0.001

Brand personality (1 = sincerity; 0 = excitement); DV = dependent variable. Coefficients for the control variables including health concern and product familiarity are not presented in the table.

personality and consumers' purchase intention (IE = −0.33, 95% CI = −0.73–0.06, included zero), which indicated that although exciting brands are perceived to be more arousal than sincere brands, arousal does not explain the variability in consumers' purchase intention toward these two types of brand personality.

Discussion

Consistent with H_1, findings in Study 1 showed that psychological distance mediates the impact of brand personality (sincerity vs. exciting) on consumers' purchase intention. Specifically, compared to exciting, sincere brand personality is perceived as more proximal and induces higher purchase intention. Moreover, arousal was not a significant mediator to underlie the variability in consumers' purchase intention toward sincere vs. exciting brands. In Study 2, we adopted a different product type (vacuum cup), and we introduced the measurement of individuals' attachment anxiety and avoidance, in order to test H_2–H_3.

STUDY 2

The core objectives of Study 2 were (1) to replicate the key findings of Study 1 with another product category and (2) to investigate the moderating role of consumers' attachment style in the impact of brand personality on purchase intention and test the mediating role of psychological distance. Specifically, we hypothesized that, under the condition of high anxiety or low avoidance, individuals perceive sincere brand as more proximal and exhibit much more preference for sincere (vs. exciting) brands.

Materials and Methods

Stimuli Selection

Two versions of an advertisement featuring a vacuum cup launched by a fictitious brand were created to manipulate the brand personality. Similar to Study 1, brand personality was manipulated via color, font, and other brand elements. In addition, the tagline in the sincere condition was "KARLO creates a healthy life with you," whereas in the exciting condition it was "Enjoy a vital life with KARLO!" Please see **Supplementary Appendix B** for stimuli.

Similar to Study 1, a pretest (n = 41) was conducted to confirm the effectiveness of brand personality manipulation. Participants were asked to rate the degree to which each brand was associated with five measurement items for sincerity traits sincerity traits ("sincere," "honest," "wholesome," "down-to-earth," "family oriented"; 1 = not at all, 7 = to a great extent; α = 0.85) and with five measurement items for exciting traits ("exciting," "unique," "young," "imaginative," "daring"; α = 0.81). The present confirmed that participants presented with the sincere advertisement rated KARLO as more sincere (mean = 4.90, SD = 0.78) than those presented with the exciting website (mean = 4.04, SD = 0.48), $F(1, 39) = 17.80$, $p < 0.001$, $\eta_p^2 = 0.31$. Similarly, participants presented with the exciting advertisement rated KARLO as more exciting (mean = 4.60, SD = 0.81) than those presented with the sincere advertisement (mean = 3.70, SD = 0.54), $F(1, 39) = 17.88$, $p < 0.001$, $\eta_p^2 = 0.31$. No significant group differences in ratings of other three brand personality dimensions (competence, sophistication, and ruggedness; Aaker, 1997) for KARLO were detected, P's > 0.10.

Participants and Procedure

One hundred thirty-five college students (51 males, 84 females, $mean_{age}$ = 20.49 years, SD_{age} = 2.22) participated and received financial rewards. None of them have participated in Study 1. Study 2 had a brand personality (sincere vs. exciting) by attachment-style (continuous) mixed-subjects design. Similar to Study 1, brand personality was manipulated in the laboratory using the context of a new product launch. Participants were told to imagine that they were selecting a vacuum cup for themselves and would be exposed to an advertisement introducing a new vacuum cup launched recently, which conveyed either a sincere or an exciting brand personality. After seeing the stimuli, participants were asked to complete a questionnaire consisting of the product evaluation similar to Study 1 and measurements of the personality traits. Purchase intention was assessed on a single item ("likely to purchase"; 1 = not at all, 7 = to a great extent). Perceived psychological distance was measured as in Study 1 (α = 0.78). Attachment style was measured on a revised version of The Revised Experiences in Close Relationships measure (ECR-R) developed by Brennan et al. (1998). Participants stated their level of agreement to statements that assessed their attachment anxiety ("I'm afraid that my friends/partner will not want to stay with me," "I often worry that my friends/partner doesn't really love me," "I worry that friends/partner won't care about me as much as I care about them," "I really worry about being abandoned"; α = 0.82), as well as their attachment avoidance ("I prefer not to be too close to a friend/partner," "I hope to be independent," "I feel anxious when I am being too close to my friend/partner," "I hope I don't rely too much on my friends/partner"; α = 0.68). To control for the possible effect of the product familiarity, product familiarity was measured on a 7-point item ("familiar with vacuum cups"). Finally, the instrument concluded with the manipulation check for brand personality mentioned in the pretest and the collection of basic demographic information.

Results

Manipulation Check: Brand Personality

Analyses of sincerity and excitement as a function of brand personality confirmed the manipulation of brand personality, such that participants perceived the sincere brand as more sincere (mean = 5.21, SD = 0.77) than the exciting brand (mean = 4.09, SD = 1.20), $F(1, 130) = 39.88$, $p < 0.001$, $\eta_p^2 = 0.24$. Similarly, participants perceived the exciting brand as more exciting (mean = 4.82, SD = 1.16) than the sincere brand (mean = 3.48, SD = 0.92), $F(1, 128) = 53.60$, $p < 0.001$, $\eta_p^2 = 0.29$.

Hypotheses Testing

We propose that purchase preference of sincere over exciting brands is more prominent for consumers with high (vs. low) attachment anxiety, which occurs via the more proximal psychological distance of sincere brands from the consumers (H_2) and propose a similar pattern for consumers with low (vs.

high) attachment avoidance (H_3). In other words, we proposed a nomological network with a mediated moderation.

Because attachment anxiety and attachment avoidance are continuous variables, we first ran a regression analysis with purchase intention as the dependent variable, and mean-centered attachment anxiety and attachment avoidance, brand personality (abbreviated as BP; 1 = sincere; 0 = exciting), and their interactions (BP × attachment anxiety; BP × attachment avoidance) as predictors. Regression analyses revealed main effects of BP (β = 0.36, t = 4.49, $p < 0.001$) and attachment anxiety (β = -0.38, t = -3.19, $p < 0.01$). No other main effect was detected. More importantly, a significant two-way interaction of BP × attachment anxiety was identified (β = 0.45, t = 3.79, $p < 0.001$). Simple slope analyses confirmed that attachment anxiety predicted increased purchase intention toward the sincere brand (β = 0.28, t = 2.34, $p < 0.05$) and decreased purchase intention toward the exciting brand (β = −0.38, t = −3.24, $p < 0.01$). However, the two-way interaction of brand personality × attachment avoidance failed to be significant (β = −0.08, t = −0.70, p = 0.49).

Next, an analysis of psychological distance, as a function of brand personality, mean-centered attachment anxiety and attachment avoidance, and their interaction (BP × attachment anxiety; BP × attachment avoidance), with the covariate controlled, yielded a significant main effect of brand personality (β = 0.23, t = 2.83, $p < 0.01$) and a marginally significant main effect of attachment anxiety (β = −0.23, t = −1.88, p = 0.06). No other significant main effect was detected. More importantly, a significant two-way interaction of brand personality × attachment anxiety was identified (β = 0.41, t = 3.42, p = 0.001). Simple slope analyses confirmed that attachment anxiety predicted increased psychological proximity toward the sincere brand (β = 0.39, t = 3.31, $p < 0.01$) and decreased psychological proximity toward the exciting brand (β = −0.24, t = −1.98, p = 0.05). However, the two-way interaction of brand personality × ×attachment avoidance failed to be significant (β = −0.11, t = −0.89, p = 0.32).

To determine whether psychological distance accounted for the moderating effect of attachment anxiety on purchase intention, we constructed a regression model with purchase intention as the dependent variable, and both the interaction of brand personality × attachment anxiety and psychological distance included as predictors. The effect of brand personality became weaker (β = 0.24, t = 3.41, $p < 0.01$) as compared to the effect detected in the first model mentioned above (β = 0.36, t = 4.49, $p < 0.001$). More importantly, the coefficient for the interaction of BP × attachment anxiety became weaker (β = 0.23, t = 2.21, $p < 0.05$) as compared to the effect detected without the mediator included (β = 0.45, t = 3.79, $p < 0.001$), whereas the effect of psychological distance was significant (β = 0.52, t = 7.03, $p < 0.001$). A bootstrapped mediated moderation analysis (Hayes, 2012; Model 8) revealed the interaction effect of BP × attachment anxiety on purchase intention was indeed mediated by psychological distance (index of mediated moderation = 0.35, 95% CI = 0.18–0.54, excluded zero). Consistent with the preceding information, conditional mediation analyses revealed that psychological distance mediated the positive impact of attachment anxiety on the purchase intention toward the sincere brand (IE = 0.22, 95% CI = 0.11–0.34, excluded zero) and meanwhile mediated the negative impact of attachment anxiety on the purchase intention toward the exciting brand (IE = −0.13, 95% CI = −0.26 to −0.01, excluded zero). These results were consistent with H_2. Inconsistent with H_3, a bootstrapped mediated moderation analysis (Hayes, 2012; Model 8) revealed the interaction effect of BP × attachment avoidance on purchase intention was not mediated by psychological distance (IE = −0.12, 95% CI = 0.32–0.07, included zero) (**Table 2**).

Discussion

Results of Study 2 not only replicated findings of Study 1 with a different product category, but also supported our H_2 on the moderating role of consumers' attachment anxiety. Specifically, the impact of brand personality upon psychological distance is more prominent among consumers with high (vs. low) levels of attachment anxiety, and therefore sincere (vs. exciting) brands are more appealing to consumers with higher level of attachment anxiety. H_3 was not supported in our study, suggesting that attachment avoidance does not moderate the impact of brand personality on psychological distance or purchase intention. The reason accounting for this result probably lies in that although individuals with high levels of attachment anxiety are afraid of developing intimate relationships, avoidant style individuals do not shun social contact altogether (Bartholomew and Horowitz, 1991; Roisman, 2006). It can be indicated from our study that how avoidant individuals evaluate the self-brand relationship is different from how they evaluate intimate

TABLE 2 | Results of mediated moderation analysis in Study 2.

	β	*t*	*P*
Step 1 (DV = purchase intention)			
BP	0.364	4.493	< 0.001
Attachment anxiety	−0.375	−3.185	< 0.01
Attachment avoidance	−0.018	−0.150	0.881
BP × attachment anxiety	0.445	3.785	< 0.001
BP × attachment avoidance	−0.083	−0.700	0.416
Step 2 (DV = psychological distance)			
BP	0.234	2.829	< 0.01
Attachment anxiety	−0.227	−1.883	0.062
Attachment avoidance	0.053	0.437	0.663
BP × attachment anxiety	0.411	3.419	0.001
BP × attachment avoidance	−0.122	−1.000	0.319
Step 3 (DV = purchase intention)			
BP	0.241	3.406	< 0.01
Attachment anxiety	−0.257	−2.532	< 0.05
Attachment avoidance	−0.046	−0.450	0.653
BP × attachment anxiety	0.230	2.208	< 0.05
BP × attachment avoidance	−0.020	−0.195	0.846
Psychological distance	0.522	7.026	< 0.001

BP, brand personality (1 = sincerity; 0 = excitement); DV, dependent variable; Coefficients for the control variable of product familiarity are not presented in the table.

relationships, in a way that avoidant individuals do not transfer the fear of developing intimate relationships to purchasing a psychologically proximal brand.

Within the marketing context, Studies 1 and 2 clarified that the proximal psychological distance induced by sincere (vs. exciting) brands is a critical variable for mediating the variability in consumers' purchase intention toward sincere and exciting brands. In Studies 3 and 4, we will further use cognitive computerized cognitive tasks to examine the effect of brand personality on psychological distance, an important driver of consumer behaviors.

STUDY 3

The purpose of Study 3 is to test the effect of personality-priming words on psychological distance using a cognitive paradigm. Our study tool was a picture-word version of the Stroop task (e.g., Arieh and Algom, 2002; Shaki and Algom, 2002). The Stroop task is a classic measure to test the selectivity of attention (indeed, its failure), to a relevant aspect of the stimuli. In this study, the picture served to create depth and conveyed various lengths of distance perceived by an observer (i.e., participant) of the word from himself/herself. A target Chinese word (i.e., a personality-priming word) appeared in the picture, which was located either near or far away from the observer. Participants were asked to complete a distance classification task with respect to the position of the target word. It is important to emphasize that the personality-priming words themselves were not words directly related to distance in any literal sense. Thus, the personality-priming words and their locations did not form Stroop-like stimuli unless the symbolic meanings of words perceived and instantly processed by the observer are associated with psychological distance.

Materials and Methods

Participants and Design

Nineteen college students (9 males, 10 females, $mean_{age}$ = 20.42 years, SD_{age} = 2.09) were recruited to participate in this study. All of them were native Chinese speakers and did not have reading disorder, with normal or rectified vision. Study 3 adopted a 2 (brand personality: sincerity vs. excitement) × 2 (location: near vs. far) within-subjects design.

Stimuli Selection

Through Google's images search tool, we selected two images of alleys with rolling hills that conveyed a clear depth perception, so that participants would be able to easily report the spatial location of an object on the picture. We made two versions of each image, one with an arrow that pointed to a relatively distal location and one with an arrow that pointed to a relatively proximal location. The printed word appeared inside the arrow, in black (font = "song" typeface, which is popularly adopted for Chinese words). The font size of the words was 35-point when they were printed on a spatially proximal arrow and 70-point when they were printed on a spatially distal arrow. Words were selected from brand personality scale developed by Aaker (1997) and constituted an initial pool of 8 items representing the two brand personality dimensions.

Procedure

Displays were generated by a computer attached to a 24-inch monitor, using 2,560 × 1,440 resolution graphics mode. To reduce head movement, a chin rest was used. The distance between the eyes of the participants and the top/bottom of the monitor was 70 and 74 cm, respectively.

Participants performed the task in individual cubicles. Each participant was first presented with an example – one of the images selected randomly for each participant. They were informed that they would next see similar images with clear depth perspectives and with similar arrows pointing to either a proximal or a distal location in the image. In the experiment trials, participants were requested to respond according to the location of the arrow, and the reaction time of each trial was recorded. Participants' responses were collected via the computer keyboard. Half of the participants were requested to respond with pressing "S" to indicate proximal spatial location and with pressing "K" to indicate distant spatial location. The response requests were reversed for the other half of the participants. It was made clear to the participants that they would probably have no problem in discriminating between proximal and distal locations, because proximal arrows were always very close to the most proximal location in the image, and distal arrows were always very close to the most distal location in the image. Participants were informed that the words, printed on the arrows, were irrelevant to the current task. The stimuli remained on the screen until the participant responded. The intertrial interval between participant's press and the display of the next stimulus was 500 ms. Error trials were followed by a 500 ms feedback beep. Thirty-two trials (2 images ×2 locations × 8 words) appeared randomly (**Figure 1**).

Results

Reaction times exceeding the mean of all correct responses by more than 3 standard deviations were excluded. Less than 1% of all observations (six trials) were removed. The mean reaction time data were submitted to a 2 (brand personality: sincere vs. exciting) × 2 (locations: near vs. far) within-subjects analysis of variance (ANOVA). The main effect of brand personality was significant, $F(1, 18) = 6.64$, $p < 0.05$, $\eta_p^2 = 0.27$, but that of the location was not significant, $F(1, 18) = 0.04$, $p = 0.84$, $\eta_p^2 = 0.002$. More importantly, a significant interaction of location and brand personality was detected, $F(1, 18) = 6.37$, $p < 0.05$, $\eta_p^2 = 0.26$, which documented the presence of an appreciable Stroop effect in this study. Participants classified distance faster when it matched the brand personality's perceived psychological distance (for congruent trials including sincere words located more proximal and exciting words farther away: mean = 696.64, SD = 205.13) than when they mismatched (for incongruent trials including sincere words located farther away and exciting words more proximal: mean = 746.00, SD = 252.67). The Stroop effect accounted to 49.36 ms. Specifically, participants classified the distance faster when sincere words were physically proximal (mean = 674.54, SD = 48.69) than when they were far

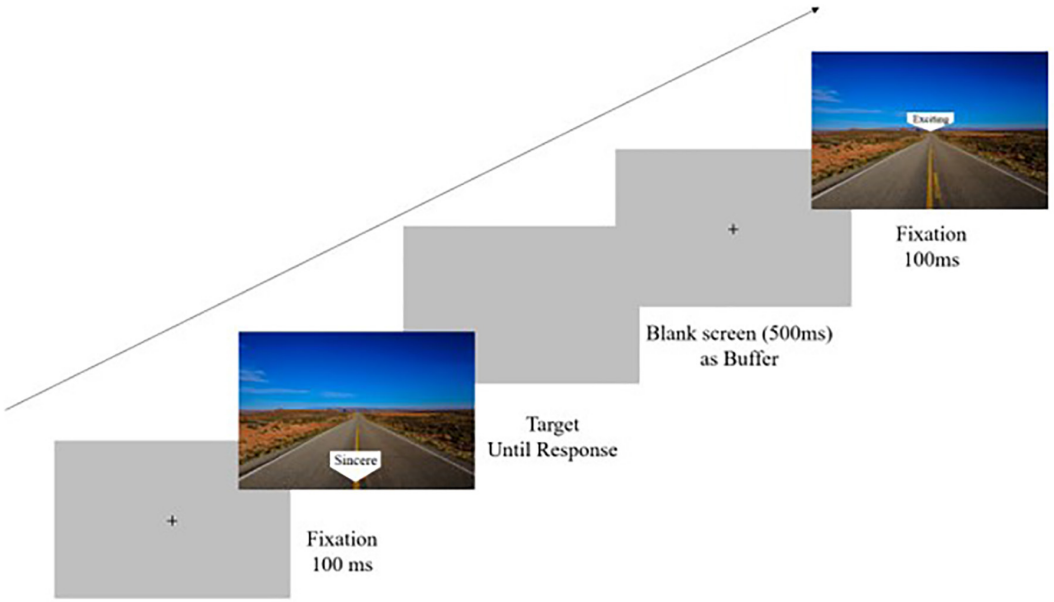

FIGURE 1 | Procedure of experiment 3.

(mean = 727.99, *SD* = 58.29), $F(1, 18) = 3.73$, $p = 0.07$, $\eta_p^2 = 0.17$. Conversely, participants classified distance faster when exciting words were physically far (mean = 718.75, *SD* = 46.12) than when they were proximal (mean = 764.99, *SD* = 58.90), $F(1, 18) = 4.35$, $p = 0.05$, $\eta_p^2 = 0.20$.

Discussion

With the use of a revised Stroop task, the results of Study 3 mirrored the effect of brand personality on perceived psychological distance documented in Studies 1 and 2. The results of the picture-word version of Stroop task clearly showed that stimuli featuring sincerity are perceived to be more proximal than those featuring excitement. In the following study, we adopted the interference task to examine the influence of the variability in psychological distance induced by different brand personality on social-based attention.

STUDY 4

Study 4 employed an interference task to investigate whether brand personality would modulate visual attention. In each trial of the interference task, a cue letter would be presented on one side of the screen. Then a same letter (in compatible trials) or a different letter (in incompatible trials) was presented on the other side of the screen. Participants were asked to respond according to the second letter presented via pressing the computer keyboard. Typically, participants' responses to the target are more rapid in compatible than in incompatible trials. Faster response in compatible trials reflects a stronger cueing effect of the consistent information, and slower response in incompatible trials reflects an articulated interference effect of inconsistent information.

Study 4 adopted a 2 (compatibility: compatible vs. incompatible) × 2 (personality: sincerity vs. excitement) within-subjects design. Personality was manipulated by two versions of cartoon characters featuring sincerity and excitement respectively. Studies 1–3 demonstrated that stimuli featuring sincerity would induce a more proximal psychological distance than stimuli featuring excitement. In this case, when stimuli featuring sincerity appear, individuals would be more sensitive to the following consistent information and would be interfered with more by the following inconsistent information. As thus, a stronger cueing effect and an articulated interference effect would be detected in the sincerity personality condition than the excitement personality condition.

Materials and Methods

Participants and Design

Forty-one students (18 males, 23 females, mean_{age} = 19.63 years, SD_{age} = 1.51) participated in this study. None of them have participated in the studies above. Study 4 adopted a 2 (personality: sincerity vs. excitement) × 2 (compatibility: compatible vs. incompatible) within-subjects design.

Stimuli Selection

Two types of cartoon figures were designed to symbolize different kinds of personality. A pretest ($n = 23$) was conducted to confirm the effectiveness of the manipulation. Participants were asked to rate the degree to which each cartoon figure had sincerity traits and exciting traits, respectively (1 = not at all, 7 = to a great extent). Results showed that sincere figures (e.g., a friendly male in suits) were perceived as more sincere (mean = 4.91, *SD* = 1.19) than exciting figures (mean = 3.63, *SD* = 1.02), $F(1, 22) = 33.86$, $p < 0.001$. Conversely, exciting figures (e.g.,

a cool male in sportswear) were perceived as more exciting (mean = 4.98, SD = 1.15) than sincere figures (mean = 3.27, SD = 1.16), $F(1, 22) = 72.86$, $p < 0.001$.

Procedure

Participants were tested individually while seated approximately 60 cm from the screen. All displays were presented on a gray background on a 24-inch monitor, using 2,560 × 1,440 resolution graphics mode. To reduce head movement, a chin rest was used. Each trial began with a presentation of a cartoon figure on one side of the screen (either left or right). The fixation was presented at the center of the screen at the same time; the visual angle between the fixation and the cartoon figure was 2°. Being stationary for 200 ms, a letter (N or E) was then presented on the existing figure. After an interval of 400 ms, another cartoon figure of the same type was presented on the other side of the screen, embedded with the same or a different letter. Participants were asked to report whether the second letter was an N or an E as quickly as possible by pressing the keyboard. In half the trials, the target and distractor were compatible (i.e., both N or both E); in the remaining half of the trials, the target and distractor were incompatible. The target and the distractor remained visible until a response was made. Participants were explicitly informed that the cartoon figures displayed were irrelevant of the task and could be ignored. The appearance of the cartoon type was in random sequence (either sincere or exciting). A 2 (compatibility) × 2 (personality) within-subjects design was used. Each participant completed 80 total trials, with 20 trials in each condition. The trials were presented at random (**Figure 2**).

Results

A 2 (compatibility) × 2 (personality) repeated-measures ANOVA indicated a significant main effect of compatibility, $F(1, 40) = 33.48$, $p < 0.001$, $\eta_p^2 = 0.46$, but no main effect of personality, $F(1, 40) = 0.39$, $p = 0.54$, $\eta_p^2 = 0.01$. As expected, the interaction between these two variables was significant, $F(1, 40) = 10.11$, $p < 0.01$, $\eta_p^2 = 0.20$. To compare the cueing effect across different types of personality, mean Response time (RT) of the compatible trials were submitted to a paired-samples t-test. Results confirmed that participants responded faster in the sincerity personality condition [$t(40) = -2.39$, $p < 0.05$, $\eta_p^2 = 0.13$]. To compare the interference effect, a paired-samples T-test of mean RT of the incompatible trials revealed that participants responded slower in the sincerity personality condition [$t(40) = 2.80$, $p < 0.001$, $\eta_p^2 = 0.16$]. These results indicated a stronger cueing effect, as well as a stronger inference effect in the sincerity (vs. excitement) personality condition.

Discussion

Results in Study 4 implied that personality-priming images could modulate the social-based visual attention. Specifically, compared to excitement, images featuring sincerity lead to a facilitation of responses with a cueing letter and a delayed response with an interferent letter, consistent with our finding, which stated that sincerity personality is perceived as more proximal than excitement personality.

GENERAL DISCUSSION

Accumulating evidence has shown that consumers are more willing to purchase sincere brands than exciting brands. The present study addresses the mechanism underlying this variability, taking a fresh perspective from psychological distance. Results demonstrate that sincere brands are perceived to be more proximal than exciting brands, such proximal psychological distance inducing more willingness to purchase sincere brands than to purchase exciting ones (Study 1). Study 2 further illustrated that attachment anxiety but not attachment avoidance affects variability in consumers' purchase intention toward brands of different personality. Specifically, purchase preference of sincere over exciting brands is more salient among consumers with high attachment anxiety as compared to consumers with low attachment anxiety. This pattern is found to occur via the more proximal psychological distance as well.

With adoption of cognitive computerized tasks, in Studies 3 and 4, we confirmed that stimuli perceived as sincere and exciting induce different responses relevant to the perceptions of psychological distance. The picture-word version of the Stroop task was adopted, and the results showed that sincere and exciting words indeed carry underlying meanings associated with psychological proximity and psychological distance, respectively (Study 3). Moreover, compared to stimuli featuring excitement, a stronger cueing effect and an articulated interference effect were detected for stimuli featuring sincerity (Study 4).

Our study makes two major contributions. First, we identify and investigate the mechanism underlying the variability in consumers' willingness to purchase toward sincere and exciting brands. We prove that psychological distance is a critical variable for mediating the variability in purchase intention and accounting for the interaction effect of attachment style by brand personality on purchase intention. The results of our studies offer valuable insights on brand positioning. Sincere personality traits associated with a specific brand would improve the development of the consumer–brand relationship and consumers' purchase behaviors, especially for attachment anxiety styles. Second, to our knowledge, this research is among the first few to introduce psychological distance and relevant cognitive paradigms into the brand personality marketing literature. Past studies have shown that spatial closeness has a direct influence on judgments of interpersonal connectedness and emotional attachment (Liberman et al., 2007a,b; Zhang and Wang, 2009). For example, it was indicated that salience of semantic concepts related to physical closeness (e.g., "nearby," "local") can lead to a closer social perception toward others (Williams and Bargh, 2008). Indeed, in our daily language, we often use "closest" friend to describe a person who cares about us the most or with whom we have a mutually strong and enduring friendship. Our present study shows that, by associating brands with human personality traits, consumers can interact with brands in ways similar to interpersonal relationship partners and often rely on psychological distance to make their purchase decisions. More importantly, findings of cognitive paradigms demonstrate the effectiveness of psychological

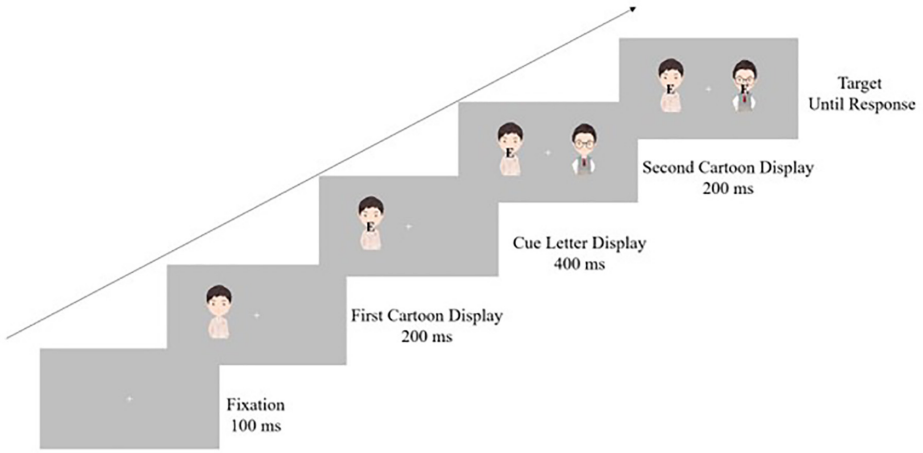

FIGURE 2 | Procedure of experiment 4. This figure explains the procedure for the compatible condition with sincerity-priming features. Participants were asked to make a response as quickly as possible when the target letter appeared.

distance perception triggered by different symbolism of brand personality, including words and images.

Several areas await future investigations. First, important distinctions should be made between when consumers use a brand as means to signal self-concept and as a relationship partner with which to interact. For example, if an exciting brand is viewed as a means to help express the self (e.g., "I am imaginative"), then consumers may be motivated to "get close to the brand" so that the boundary between the self and the brand is blurred. In contrast, if consumers view brands as relationship partners, they would prefer sincere brands over exciting brands when consumers want to develop stable social relationships. When and how each process occur warrant further study. Second, we have only examined two types of brand personality. Future research could look at the full ranges of personalities that brands may be associated. It would be interesting to investigate whether there is significant difference in psychological distance between sophisticated, competent, and rugged brands and the following influence on consumers' purchase behaviors.

CONCLUSION

With the use of self-report measurements and cognitive paradigms, our research advances the literature of brand personality by probing the important role of psychological distance. Compared to exciting, sincere brands are perceived to more proximal and psychological distance mediating the relationship between brand personality (sincerity vs. excitement) and consumers' purchase intention. Moreover, the impact of brand personality on psychological distance and purchase intention is more prominent for consumers with higher attachment anxiety. In summary, our research further elaborates on the variability of consumer behavior toward sincere and exciting brands and contributes to the broader discussion about the driving force of psychological distance in consumer behaviors.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TH and BS conceived of the idea and designed the studies. TH collected and analyzed all the data. BS mentored the whole processes. TH and BS approved the final manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.01258/full#supplementary-material

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BRIEF RESEARCH REPORT
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Mental Shopping Calculations: A Transcranial Magnetic Stimulation Study

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One of the most critical skills behind consumer's behavior is the ability to assess whether a price after a discount is a real bargain. Yet, the neural underpinnings and cognitive mechanisms associated with such a skill are largely unknown. While there is general agreement that the posterior parietal cortex (PPC) on the left is critical for mental calculations, and there is also recent repetitive transcranial magnetic stimulation (rTMS) evidence pointing to the supramarginal gyrus (SMG) of the right PPC as crucial for consumer-like arithmetic (e.g., multi-digit mental addition or subtraction), it is still unknown whether SMG is involved in calculations of sale prices. Here, we show that the neural mechanisms underlying discount arithmetic characteristic for shopping are different from complex addition or subtraction, with discount calculations engaging left SMG more. We obtained these outcomes by remodeling our laboratory to resemble a shop and asking participants to calculate prices after discounts (e.g., $8.80–25 or $4.80–75%), while stimulating left and right SMG with neuronavigated rTMS. Our results indicate that such complex shopping calculations as establishing the price after a discount involve SMG asymmetrically, whereas simpler calculations such as price addition do not. These findings have some consequences for neural models of mathematical cognition and shed some preliminary light on potential consumer's behavior in natural settings.

Keywords: mathematical cognition, arithmetic operation, functional lateralization, posterior parietal cortex, transcranial magnetic stimulation study

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INTRODUCTION

Neuropsychological studies in patients and neuroimaging reports in healthy individuals show that the neural circuits for mental calculations form a complex network of interacting areas. They involve the parietal lobes, e.g., the bilateral intraparietal sulcus, the posterior subdivisions of the superior parietal lobules, and the left angular and supramarginal gyri of the inferior parietal lobule (Gobel et al., 2001; Naccache and Dehaene, 2001; Dehaene et al., 2003, 2004; Eger et al., 2003; Fias et al., 2003; Piazza et al., 2004; Pinel et al., 2004; Nieder, 2005; Sato et al., 2007; Andres et al., 2008; Brozzoli et al., 2008; Domahs et al., 2008, 2010; Kaufmann et al., 2008), as well as the temporal lobes, e.g., the posterior inferior temporal gyrus (Daitch et al., 2016; Hermes et al., 2017; Yeo et al., 2017; Pinheiro-Chagas et al., 2018, 2019) and even the left frontal lobe, with the Broca's area and its vicinity (Schmithorst and Brown, 2004; Shuman and Kanwisher, 2004; Majerus et al., 2010). While it is still unknown what subdivision

of this network is the most critical for mental arithmetic, there is some agreement that such an area should be located in the posterior parietal cortex (PPC) on the left (Dehaene et al., 2004; Nieder, 2005). However, recent studies also suggest that the right PPC may exert some role in such mental operations too (Arsalidou and Taylor, 2011; Knops and Willmes, 2014; Sokolowski et al., 2017; Mock et al., 2018). Indeed, there is evidence that the more difficult/complex the arithmetic task, the more profound the engagement of the right PPC (Fehr et al., 2008; Hamid et al., 2011; Vansteensel et al., 2014; Klichowski and Kroliczak, 2017; Mock et al., 2018; cf. Semenza and Benavides-Varela, 2017; Semenza et al., 2017). Whether or not these earlier findings are relevant for more down-to-earth tasks such as shopping arithmetic, especially discount calculations, still remains to be seen.

The key evidence to resolve this issue could come from the use of transcranial magnetic stimulation (TMS), in particular repetitive TMS (rTMS), because TMS makes it possible to demonstrate the causal role of a selected brain area in the operations in question. Meanwhile, rTMS has been used only in studies on simple mental calculations (i.e., based on single digits; Salillas et al., 2012; Maurer et al., 2015) that are far removed from such daily chores as calculating prices in consumers' heads. To the best of our knowledge, only one rTMS study thus far has examined multi-digit mental addition (e.g., 23 + 26) and subtraction (e.g., 49–26), which are much closer to numbers that consumers are likely to operate on, showing an atypical lateralization of the rTMS effect (right > left) for the supramarginal gyrus (SMG), a part of PPC (Montefinese et al., 2017). This effect is probably related to the fact that in the case of complex mental calculations on rather unfamiliar or accidental numbers, the visual working memory is strongly burdened, and there is also a need for maintaining intermediate results, and therefore, increased attentional resources (Majerus et al., 2010; Fias et al., 2013; Sokolowski et al., 2017). In fact, such difficult, memory-based, processes are supported by the right SMG (Mock et al., 2018). However, it is not known whether or not the right SMG is involved in other types of complex arithmetic, e.g., calculations of sale prices that are characteristic of everyday human activities (Dastjerdi et al., 2013). An example is shopping, wherein for discounts one typically subtracts a percentage value from small multi-digit numbers, i.e., the ones with values after the decimal point (e.g., 8.80–50%).

Depending on the type of task, as well as on the conditions in which a given task is performed, different neural mechanisms might be invoked for disparate kinds of mental calculations (Curtis et al., 2016; Yusoff et al., 2016; Beller et al., 2018; Hickendorff et al., 2019). For example, complex addition or subtraction is based on mechanisms that are distinct from the ones for complex multiplication or division. Similarly, school math calculation may engage different neural resources from those used in a store. Indeed, different complex calculations can be associated with disparate neural processes (Li et al., 2018), and therefore, can differentially/asymmetrically engage different subdivisions of the relevant neural circuits (Yusoff et al., 2016; Hawes et al., 2019). Thereby, one cannot assume that in the case of sale price calculations the role of the right SMG will be the same as in the case of multi-digit mental addition or subtraction (Montefinese et al., 2017). In fact, operating on familiar numbers that are often seen on shop labels (e.g., −50% or −25%) – even though they are multi-digit, and therefore, complex – may not require right-hemisphere resources such as visual working memory to the extent than does operating on unfamiliar numbers (which put greater load on memory capacity, and consequently, require critical engagement of right SMG; Rosenberg-Lee et al., 2011; Bloechle et al., 2016; Nemati et al., 2017; Mock et al., 2018). Therefore, we hypothesized that the right, as compared to left SMG, might be less critical for calculations of sale prices characteristic for consumers' daily behavior. We did not expect to see any differential engagement of SMG from the two hemispheres in our control task, that is, price addition.

The outcomes we obtained do not rule out that the right SMG is involved in complex mental calculation, but its greater engagement is not specific for all complex arithmetic. Indeed, in discount arithmetic its role is less pronounced and the left SMG dominates instead. While these findings may have some consequences for neural models of mathematical cognition too, they provide one of the first pieces of evidence unveiling the neural substrates critical for consumer's behavior.

MATERIALS AND METHODS

Our study was assessed and approved by the local Ethics Committee for Research Involving Human Subjects (opinion #9/10/01/2018). As such, all procedures and manipulations were carried out in accordance with the principles of the Declaration of Helsinki 2013 and its recent amendments.

Participants

Twenty healthy volunteers (14 women, age: 20–27, mean = 20.9, *SD* = 1.6) who took part in this study gave their written informed consents prior to participation. All participants had normal or corrected-to-normal visual acuity. As confirmed by the results of the revised version of the Edinburgh Handedness Inventory (Dragovic, 2004), nearly all volunteers (18) declared themselves as right-handed (*laterality quotient* = 93.6, *SD* = 16.3, *laterality score* = 60.0, *SD* = 12.4), whereas two of them were left-handed (*laterality quotient* = −58.3, *SD* = 58.9, *laterality score* = −37.5, *SD* = 38.9). All participants were reimbursed for their time and efforts, obtaining 50 PLN (approximately $13 USD) in the form of a gift card to redeem at a shop with books and CDs.

Stimuli and Procedure

To emulate the processes characteristic for shopping, we remodeled our laboratory so that it resembled a shop (see **Figure 1**). For example, at the entrance to the lab there was a shop sign with the opening hours. Next to the TMS chair, we put a shopping basket full of to-be-purchased items, and a supermarket shelf displaying different products and their prices.

We used stimuli in the form of shop labels with numbers consisting of values with decimal points and values of discounts.

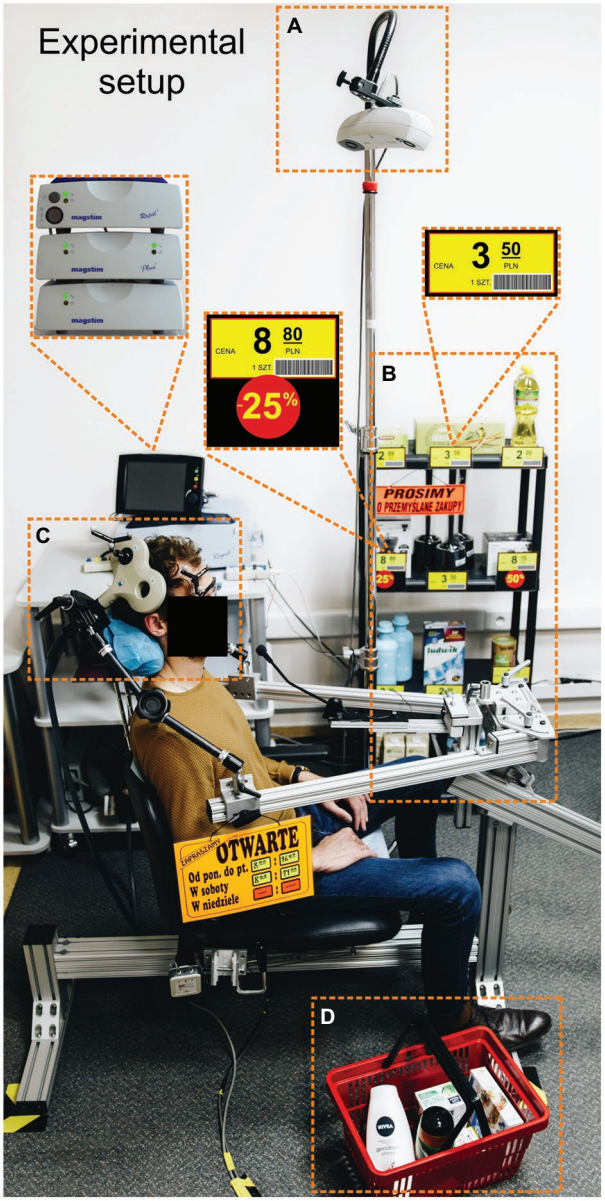

FIGURE 1 | Experimental setup. **(A)** The tracking system for the head and coil. **(B)** A supermarket shelf. **(C)** One of the possible positions of the TMS coil (here over the right SMG). **(D)** A shopping basket. The translations of labels in Polish are the following: "cena" = "price," "1 szt." = "one piece," "prosimy o przemyslane zakupy" = "please purchase carefully," and "otwarte" = "open".

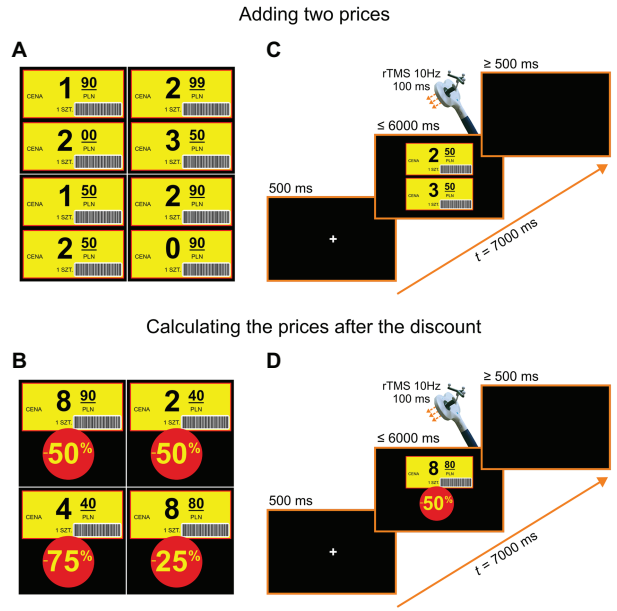

FIGURE 2 | Example stimuli and trial structures. **(A)** Examples of stimuli for adding two prices. **(B)** Examples of stimuli for calculating the price after the discount. **(C)** Trial structure for adding two prices: In each trial, after a fixation point presented on a black screen for 500 ms, two shop labels were shown for a maximum of 6 s. After the onset of a participant's vocal response, a black screen was introduced for a period of "6.5 s minus a response time" prior to the next trial (or in its absence, after a 6-s stimulus duration, for additional 500 ms). **(D)** Trial structure for calculating the prices after a discount: In each trial, after a fixation point presented on a black screen for 500 ms, one shop label and a discount value was shown for a maximum of 6 s (in the case of no response). As before, after the onset of a participant's vocal response, a black screen was introduced for a period of 6.5 s minus a response time or minus stimulus duration. The translations of labels in Polish are the following: "cena" = "price", "1 szt." = "one piece".

Example stimuli are shown in **Figures 2A,B**. A participant's task was to state the price after a discount (e.g., 8.80 PLN − 50% = 4.40 PLN, see **Figure 2D**), and in the control task, a sum of two prices (e.g., 2.50 PLN + 3.50 PLN = 6 PLN, see **Figure 2C**). The two tasks were presented in counterbalanced blocks of trials. The order of trials within blocks was pseudorandomized for different participants. Each block consisted of 40 trials, including 20 trials with rTMS. The whole study consisted of two sessions: one with stimulation over the right SMG and the other over the left SMG, with the order of stimulation sites counterbalanced across participants. Before the actual experiment, a noTMS training session (i.e., two blocks consisting of 10 trials) was administered. The stimuli used during the training session did not appear in the subsequent experiment.

A given stimulus was displayed on a 119.38 cm (47-inch) LG® TV screen (60 Hz, LG Electronics Inc., Seoul, Korea) and placed in front of the TMS chair at a distance of 2.28 m. Stimulus presentation was controlled by Cedrus® SuperLab for Windows version 4.5.4 (Cedrus® Corp., San Pedro, CA, USA) installed on a Dell® OptiPlex® 7010 computer (Dell Inc., Round Rock, TX, USA) and synchronized with the TMS stimulator using National Instruments PCI-DIO24 Digital I/O Card. Participants provided their answers vocally, and the experimenter constantly monitored their accuracies. Response times (RTs) – as measured by the onsets of vocal reactions – were detected by the SV-1 Smart Voice Key (Cedrus® Corp., San Pedro, CA, USA). A given stimulus was preceded by a fixation point in the form of a white cross over a black background and displayed for 500 ms. Following a response or after 6 s in the case of no response, a black screen was introduced between successive trials. Its duration was equal to 6.5 s minus RTs for the stimulus preceding it or 500 ms, if the participant did not provide an answer.

Thus, the duration time for one trial was 7 s in total, but given that it was the experimenter who initiated the next trial only after confirming that the coil is still in the proper place, there was no risk of accumulation effects for subsequent series of stimulations (Rossi et al., 2009).

rTMS Protocol

We adopted an rTMS protocol from an earlier study by Montefinese et al. (2017). Following the onset of a stimulus, namely at 100 ms, the rTMS train consisting of three (10 Hz) pulses – i.e., the first pulse at 100 ms, the second at 200 ms, and the last one at 300 ms – was delivered with a Magstim® Rapid 2 Plus 1 stimulator using a figure-of-eight coil (with the inner diameter of 70 mm). The angle of the coil relative to the mid-sagittal plane of the participant's head was maintained at 45°, as it is the optimal coil orientation for stimulating PPC areas (Janssen et al., 2015). As in previous studies, a fixed stimulation intensity of 65% of the maximum stimulator output was used (for a review of the justifications for using fixed stimulation intensity, see Robertson et al., 2003; Vesia et al., 2010; Montefinese et al., 2017). Such stimulation protocol should result in a slowdown of RTs following rTMS. The TMS targets (the right and left SMG) were located with frameless stereotaxic neuronavigation (Brainsight® Frameless, Rogue Research Inc., Montreal, QC) and marked on the MNI ICBM 152 average brain template. Subsequently, participants' brains were warped to this standard space with the Brainsight 2.3.9 registration algorithm for the MNI model head, utilizing five best landmarks, such as the frontmost, backmost, topmost, leftmost, and rightmost points on the skull in the scaling-step procedure. The coordinates of the SMG were selected based on previous studies (e.g., Potok et al., 2019; for details, see **Figure 3**). The positions of the coil and the head were constantly monitored with the Polaris® Vicra Optical Tracking System (Northern Digital Inc., Waterloo, ON, Canada) in real time (see **Figure 1A**). The coil was held tangentially and perpendicular to the surface of the scalp, its position was secured with a dual rod articulated arm (Manfrotto® 244N Variable Friction Magic Arm, Bassano del Grappa, Italy, see **Figure 1C**), and if necessary fine-tuned on-line by the experimenter. Moreover, to minimize head movements, participants' heads were immobilized with the headrest and side support (see **Figure 1**).

Data Analyses

In addition to comparisons between means, the main dependent variable in the critical analyses described below was the difference in RTs between rTMS over the left SMG and rTMS over the right SMG, referenced to noTMS baseline. In such comparisons, negative values indicate response facilitation and positive values indicate response delay following rTMS. The adopted level of significance was $\alpha = 0.05$. For RTs accompanying correctly performed tasks, outliers greater than 6 s were discarded. All statistical analyses were carried out using IBM® SPSS Statistics® for Mac Version 26.0 (IBM Corp., Armonk, NY, USA). To compare RTs in disparate conditions and differences between rTMS effects over the left and right SMG, the following analyses were performed. Because the two tasks require quite different calculations, we ran two separate repeated-measures analyses of variance (rmANOVAs), one for adding prices and one for calculating discounts, with neural state (noTMS, rTMS-over-the-left-SMG, and rTMS-over-the-right-SMG) as the within-subjects factor. The necessary *post hoc* tests were performed with additional Bonferroni correction.

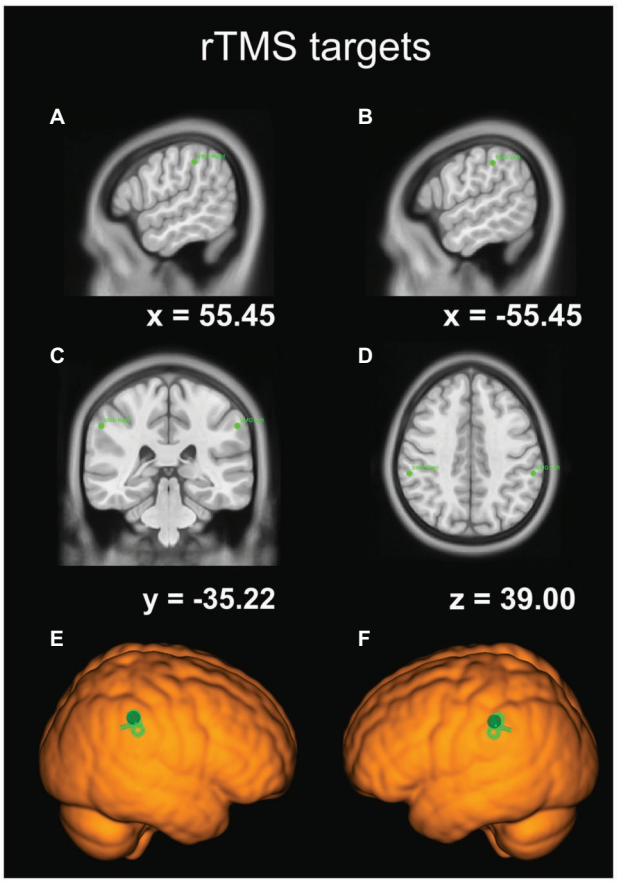

FIGURE 3 | The coordinates of our rTMS targets in the Montreal Neurological Institute (MNI) template-brain space. **(A)** The sagittal view of the right SMG site. **(B)** The sagittal view of the left SMG site. **(C)** The frontal-plane view. **(D)** The transverse-plane view. **(E)** TMS target site rendered over the standard brain with TMS coil orientation for the right SMG. **(F)** TMS target site rendered over the standard brain with TMS coil orientation for the left SMG.

RESULTS

Neither the accuracy for adding prices nor calculation of discounts was affected by rTMS applied to the left or right SMG. Therefore, further analyses are limited to RTs for correctly performed calculations in each task.

The following rmANOVA for adding two prices revealed no significant effect whatsoever, regardless of the stimulation side ($F_{(2,\ 38)} = 0.02$, $p = 0.98$, see **Figure 4A**, where these results are expressed as difference scores, relative to noTMS baseline). Yet, for discount calculations rTMS affected RTs

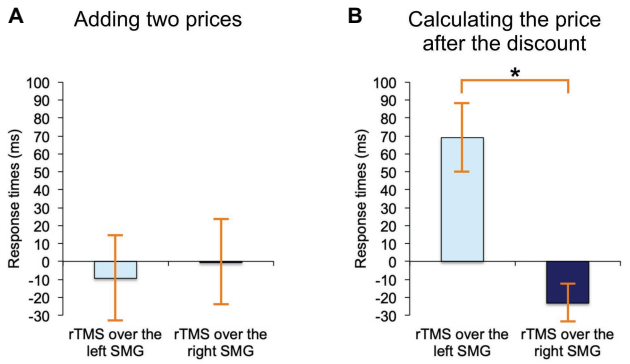

FIGURE 4 | Results. **(A)** Adding two prices on shop labels: When we contrasted rTMS-over-the-left-SMG trials and rTMS-over-the-right-SMG trials, there were no significant differences in response times. **(B)** Calculating the prices after a typical shopping discount: When we contrasted rTMS-over-the-left-SMG trials with rTMS-over-the-right-SMG trials, there was a significant delay in response times following left SMG stimulations. Asterisk (*) indicates significant p ($p < 0.05$) and "0" the no-stimulation baseline. Error bars depict standards errors of the means.

differently ($F_{(2,\ 38)} = 3.6$, $p < 0.05$), and the effect was such that only rTMS applied to the left SMG, as compared to right SMG, resulted in a significant slowdown of RTs (the difference between means = 92 ms, *SE* = 34 ms, *Bonferroni-corrected* $p < 0.05$). These results are, again, expressed as difference scores in **Figure 4B**. None of the results changed when the two left-handed participants were removed.

DISCUSSION

The outcomes of this study, based on the selected stimulation coordinates, as well as our shop-price label set, clearly show that it was the left SMG, as compared to its counterpart on the right, that was involved more (i.e., was asymmetrically engaged) in such shopping arithmetic as calculating discounts. The same type of stimulation, on the other hand, did not show any hemispheric asymmetries for adding prices. Discount calculation, a kind of task which is frequently performed by consumers before purchasing items in large superstores must, therefore, be dependent on a different involvement of key areas of the neural circuits underlying complex mental arithmetic (cf. Montefinese et al., 2017). One can only speculate that in less familiar settings and with less common prices/labels, a different asymmetric engagement of SMG would be revealed. Whether or not, under such circumstances, consumers are likely to calculate real prices after discounts, rather than trusting the sellers that there are bargains behind the "–XX%" labels, is an open question. Yet, consistent with some earlier evidence discussed above, if the size of the discount (the real price) was to be compared across different stores, the neural asymmetry for such processing could easily change its direction.

Importantly, our results indicate that the specific stimulation site of our choice, located in a rather anterior subdivision of the left SMG, plays a causal role in such highly complex arithmetic as discount price calculations. The greater engagement of left SMG, as compared to the right one, is consistent with a notion that this subdivision of PPC is also a part of the praxis representation network (PRN) for representing and sequencing highly complex and skilled actions in the typical brain (Przybylski and Kroliczak, 2017; see also Klichowski et al., 2020). After all, mathematical cognition is often linked to skilled manual/finger operations, and thus praxis (Rugani et al., 2017; Ras et al., 2019). Such embodiment of mental calculation may partly result from counting out loud and using fingers in learning arithmetic in childhood, when counting is a huge challenge (Brozzoli et al., 2008; Domahs et al., 2008). Because it takes longer for children to use fingers for more complex calculations than for less complex ones, therefore, the asymmetrically organized, more left-lateralized PRN can be a common framework for these types of mental arithmetic (Rapin, 2016).

Consistent with some of the above-mentioned arguments, it is quite unlikely that disparate kinds of mathematical, algebraic, or even shopping operations on price label contents or money, would be critically contingent on one specific mechanism, whether or not linked to SMG as a dominant node in a neural circuit. In fact, earlier research (e.g., Fias et al., 2003; Harvey et al., 2017; Kersey and Cantlon, 2017) shows the involvement of the intraparietal sulcus, the nearby subdivisions of the superior, as well as the inferior parietal lobule (including the angular gyrus) in different tasks involving numerosity processing and numbers. Thus, our null effect following right SMG TMS in consumers' discount calculations does not preclude that more posterior or superior stimulation sites would reveal their causal contributions to such a task. Indeed, the outcomes of an earlier study by Montefinese et al. (2017) give pointers as to what kinds of calculations and stimulation sites should be used to disclose disparate neural mechanisms contributing to higher-level processing of numbers or supporting operations for them. Further questions to be also considered are differences in the timing when specific nodes of such a network contribute to disparate calculation tasks. It is, for example, quite possible that a selection of a different stimulation interval could interfere more with the discount-calculation task studied here. Whether or not this would also require different stimulation coordinates is yet another question to be addressed in future studies.

In sum, based on evidence from rTMS, our report demonstrates that left SMG, as compared to its right counterpart, plays a greater role in calculating prices after discounts. No effect of rTMS applied to left or right SMG was observed in our control task, that is, price addition. Yet, following study conclusion our participants claimed that TMS affected their ability to perform both tasks. This was clearly not the case. A change in protocol – including different timing of stimulation intervals, e.g., better correlated with proper chunking of responses leading to successful price calculations, would be required to show a casual contribution of SMG (especially SMG on the right) or other brain areas to both of the studied, but also related, tasks. While our positive findings add new knowledge to basic understanding of parietal lobe contributions to shopping mental calculations, further research is no doubt needed to

elucidate the complexities of neural contributions to more sophisticated consumers' behavior, both in and well beyond their self-reports.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics committee of Faculty of Psychology and Cognitive Science, Adam Mickiewicz University, Poznan, Poland. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

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

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SYSTEMATIC REVIEW
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The Role of Diet, Eating Behavior, and Nutrition Intervention in Seasonal Affective Disorder: A Systematic Review

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Background: Seasonal affective disorder (SAD) is a biological and mood disorder with a seasonal pattern. Dietary intervention and nutritional status have been reported to affect SAD severity. The objective of this study was to systematically review the evidence of associations between SAD and diet, eating behavior, and nutrition intervention.

Methods: We performed a comprehensive search of MEDLINE, EMBASE, Web of Science, and Google Scholar from inception up to July 1, 2019. Studies that examined diet and eating behaviors in SAD patients and tests of nutrition interventions for SAD were included. Two independent investigators extracted data based on study designs, participants, outcomes, exposures, and association measures.

Results: Eleven studies were included: six studies examined distinctive dietary patterns and eating behaviors in SAD patients and five studies explored the efficacy of nutrition interventions for SAD. Vegetarianism and alcoholism were associated with higher SAD prevalence, but normal alcohol intake was not correlated with SAD severity. Compared with non-clinical subjects, SAD patients tended to consume significantly larger dinners and more evening snacks during weekdays and weekends and exhibit a higher frequency of binge eating, external eating, and emotional eating. Additionally, compared to healthy controls, SAD patients presented more cravings for starch-rich food and food with high fiber. However, neither the ingestion of carbohydrate-loaded meals nor Vitamin D/B12 supplementation showed benefit for SAD.

Conclusion: Studies suggest that SAD patients may exhibit distinctive diet preferences and eating behaviors, but no current nutrition intervention has demonstrated efficacy for ameliorating SAD symptoms. Further evidence is needed from randomized controlled trials with larger sample sizes and longer durations.

Keywords: seasonal affective disorder, depression, diet, eating behavior, nutrition intervention, supplementation

INTRODUCTION

Seasonal affective disorder (SAD) is an almost-recurring annual depression with seasonality due to the alteration of mood, hormones, and gene expressions (Wirz-Justice, 2018). The onset of depression typically appears in autumn or winter with subsequent remission in spring or summer (Meesters et al., 2016). In the revised version of the Diagnostic and Statistical Manual of Mental Disorders III (DSM-III-R), the characteristics of SAD were first described by Rosenthal et al. as hypersomnia, overeating, and symptoms that respond to changes in climate and latitude (Rosenthal et al., 1984). The Seasonal Pattern Assessment Questionnaire (SPAQ) is frequently used as a self-administered screening tool for SAD in adult clinical and subclinical samples (Magnusson, 1996; Murray, 2003; Morales-Munoz et al., 2017). According to the DSM-5 guidelines, the diagnostic criteria of SAD include a history of over two depressive episodes and a seasonal pattern of depression in consecutive years (Dittmann et al., 1994; Battle, 2013).

A season pattern can be apparent in either major depressive disorder or bipolar disorder. Patients with bipolar disorder may exhibit symptoms of both depression and mania or hypomania, as opposed to recurrent depression (Gupta et al., 2013). SAD shows a regular progressive association between the onset of depression and the time of year and a full diminution of depressive symptoms at a certain point of the year. This distinguishes SAD from non-seasonal depression. Approximately 1–2% of the U.S. population experiences SAD annually, with symptoms present for around 40% of the year (Kurlansik and Ibay, 2012). Owing to its recurrence and long duration, SAD is considered a serious mental health disorder that imposes negative influences on patients' daily lives (Rohan et al., 2009). Light therapy, pharmacotherapy, and cognitive behavior therapy are common interventions for SAD patients. However, to this date, no single therapy or combination of therapies has been found to be superior (Kurlansik and Ibay, 2012).

Recent findings have shown that food or nutrition supplements and dietary patterns may affect the development of major depression disorders (Shipowick et al., 2009; Kerr et al., 2015; Deacon et al., 2017; Opie et al., 2018), while a deficiency of certain nutrients can be identified as predictors for depression (Chong et al., 2014). It has been reported that patients with depression symptoms tend to consume more carbohydrates and prefer night eating (Danilenko et al., 2008), leading to overeating and overweight (Rosenthal et al., 1984; Donofry et al., 2014). Accumulating evidence has shown that vitamin D deficiency is associated with the progression of depression (Shipowick et al., 2009; Gu et al., 2019). One systematic review with a meta-analysis of 31,424 participants revealed an increased odds ratio of depression for the lowest vs. highest vitamin D categories in the cross-sectional studies and a significantly increased hazard ratio of depression for the lowest vs. highest vitamin D categories in cohort studies (Anglin et al., 2013), raising the possibility that vitamin D supplementation may mitigate the development of depression symptoms. Other nutrients, such as B vitamins, omega-3 polyunsaturated fatty acids, zinc, and antioxidants, are also essential for neural functions. Reports show that the deficiency of these nutrients may result in altered memory function, cognitive impairment, and the development of a major depressive disorder (Sarris et al., 2015; Mikkelsen et al., 2016).

In addition to single macro- or micro-nutrient status, diet, dietary pattern, and eating behaviors were also altered among patients with depression symptoms. Converging evidence from laboratory, population research, and clinical trials suggest that a healthy diet and dietary patterns, such as the traditional Mediterranean-style diet and the Dietary Approach to Stop Hypertension diet, may lower the risk for depression (Opie et al., 2017, 2018; Khayyatzadeh et al., 2018). However, most reviews considered depression, in general, and a few imposed a focus on SAD. In addition, previous reviews on certain nutrients and their link to SAD concentrated on a single nutrient or class of nutrients, such as vitamin D.

Considering that there is limited research showing a broad picture of how eating style and nutrient intake changes in SAD patients, our current work aims to systematically review the evidence on whether diet and eating behavior are altered among the SAD population and how nutrition intervention influences the development of SAD.

METHODS

Literature Search

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for conducting a systematic review. We registered our search protocol on PROSPERO on July 4, 2019. We performed a comprehensive search of MEDLINE, EMBASE, Web of Science, and Google Scholar from inception up to July 1, 2019. A combination of Medical Subject Heading terms and keywords were input into each database. After all of the records were organized and duplicates were excluded, two independent investigators (Y. Yang, S. Zhang) screened the titles and abstracts. The search terms are listed in **Figure 1**.

Eligibility

To obtain original studies on the effect of diet, eating behavior, and dietary supplements in SAD, we applied the following eligibility criteria and included studies if they have:

- patients with SAD confirmed by DSM-III-R, DSM-IV, DSM-IV-TR, and DSM-5, Rosenthal criteria for trials developed before DSM-III-R or patients with SAD screened by SPAQ
- included one of the following study designs: prospective cohort, cross-sectional, case-control (nested case-control and case-cohort), randomized controlled trials (RCTs), and baseline of intervention studies
- diet, dietary pattern, and eating behaviors measured with valid and established questionnaires
- outcomes related to SAD severity, mood, or changes in dietary or eating behavior and nutritional biomarkers
- provided a means or frequency report and statistical and/or epidemiological association measures

We excluded studies if the participants had other major depressive symptoms (such as bipolar disorder) or other types

Databases: MEDLINE, EMBASE, Web of Science and Google Scholar

SEARCH 1
Nutrition Terms: nutrition (MeSH[1], ti/ab[2]), nutr* (ti/ab), food (MeSH, ti/ab), vitamin (MeSH, ti/ab), mineral (MeSH, ti/ab), dietary supplement (MeSH, ti/ab), supplement* (ti/ab), nutrients (MeSH, ti/ab), diet (MeSH, ti/ab), alcohol (MeSH, ti/ab), fatty acids (MeSH, ti/ab), protein (MeSH, ti/ab), amino acids (MeSH, ti/ab).

AND

SAD Terms: seasonal affective disorder (MeSH, ti/ab)

SEARCH 2
Nutrition Terms: as above

SAD Terms: winter depression (MeSH, ti/ab)

[1]MeSH: Medical Subject Headings;
[2]ti/ab: title or abstract

FIGURE 1 | Search strategy.

of physiological stress. We also excluded studies that assessed outcomes only by medication use, exemplified by noting the use of an antidepressant itself as the diagnosis of depression without employing a symptom questionnaire, screening measure, or diagnostic assessment. In addition, studies that gave nutrition supplementation through means other than oral administration were also excluded.

Data Collection

Data collection was performed by two independent investigators (Y. Yang, S. Zhang) using a structured form. Minor discrepancies were resolved by consensus between the investigators. When major discrepancies occurred, a third investigator (J. Cheng) would be involved to make a final decision. When dealing with multiple endpoints, we only selected the outcomes that were related to SAD severity, mood changes, or the changes in diet or eating behavior and nutritional biomarkers. The following information was extracted from each included study: study characteristics (first author, study country, year of the study, study design, and sample size), participant characteristics (age), assessment of, or screening for, SAD (SAD screen tool), characteristics of exposure (diet or eating behavior, supplement type, and exposure assessment tool), outcome characteristics (outcome type, assessment tool), results (means or frequencies, comparison of the groups, and odds ratio), and conclusion. Extra information was extracted for RCTs: study duration, interventional group participant number, and control group participant number.

Tables were constructed to summarize the data. For studies showing statistical and epidemiological associations, the more complete measure of variability was presented (95% confidence intervals or *p*-value). The methods used for statistical analysis were listed with the conclusion of each study.

Risk of Bias Assessment

Two independent investigators assessed the risk of bias in the included studies (X. Zhang, Y. Xu). Any disagreements were discussed between the investigators until a consensus was reached. The methodological quality of the included studies was evaluated by utilizing the Quality in Prognostic Studies tool for observational studies (Hayden et al., 2013) and the Cochrane Collaboration's tool for assessing the risk of bias in RCTs (Higgins et al., 2011).

The Quality in Prognostic Studies tool by Hayden et al. provided six important risk domains to consider when evaluating validity and bias in studies of prognostic factors: participation, attrition, prognostic factor measurement, confounding measurement and account, outcome measurement, and analysis and reporting (Hayden et al., 2013). Even though the Quality in Prognostic Studies tool was established for prognostic studies, "prognoses" are similar to "risks" in epidemiology (Sparling et al., 2017). The Cochrane Collaboration's tool covers six domains of bias: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Within each domain, evaluations are made for one or more items to cover various aspects of the domain or different outcomes (Higgins et al., 2011).

The confounding domain was assessed based on potential confounders being controlled for and the method that was utilized to control them. Bennett et al. reported several socioeconomic and psychosocial variables that showed associations with both depression and eating behaviors, such as a history of depression, overall wellness status, social support, and income and employment, for example (Bennett et al., 2004). Studies that did not control for any of these confounders were rated as having a high risk of bias. Studies partially including these confounders were rated as having a medium risk of bias,

and studies that accounted for all the confounders were rated as having a low risk of bias. In general, we rated the risk of bias by evaluating the prompting items within each domain. The judgments about the risk of bias for each domain were established based on the information on the prompting items provided by the studies, and each domain was rated as having a high, moderate, or low risk of bias after a comprehensive evaluation of the prompting items.

RESULTS

Study Selection

The process of study selection is presented in the flowchart in **Figure 2**. The search through the three electronic databases yielded 659 results, of which 589 were screened by title and abstract after excluding duplicates. Overall, 551 articles were excluded because they did not meet the inclusion criteria, which led to a total of 38 potential studies selected for full-text review. Among them, studies were excluded for not focusing on SAD ($n = 12$), including subjects with other major depression as comparisons ($n = 1$), outcomes unrelated to our objective ($n = 3$), being review articles ($n = 2$), the full text not being available ($n = 1$), supplementation being given not through oral administration ($n = 2$), not involving dietary intervention ($n = 5$), and not using a validated tool for SAD screening ($n = 2$). In total, we included data from 11 studies in the current systematic review (Krauchi and Wirz-Justice, 1988; Rosenthal et al., 1989; Berman et al., 1993; Oren et al., 1994; Krauchi et al., 1997; Danilenko et al., 2008; Mischoulon et al., 2010; Donofry et al., 2014; Frandsen et al., 2014; Meesters et al., 2016; Morales-Munoz et al., 2017).

Studies were grouped according to three categories of exposures: (1) diet or dietary patterns ($n = 3$), (2) eating behaviors ($n = 4$), and (3) nutrition supplementation ($n = 5$). Among them, one study fits two categories, so the information within this study was extracted separately. Specifically, the studies in categories 1 and 2 are observational studies with a total of 13,360 subjects, and the studies in category 3 are RCTs with 203 participants in total. The characteristics of the included studies evaluating the associations between diet, eating behaviors, and nutrition intervention and SAD are listed in **Tables 1–3**, respectively.

Diet, Dietary Pattern, and SAD

Vegetarianism

One cross-sectional study investigated the possible link between vegetarianism and SAD (Meesters et al., 2016). By using available data from the Finnish national FINRISK 2012 study and data from the outpatient clinic for SAD in the Netherlands, the author of that study found an association between being vegetarian and SAD. They revealed that 14.6% of the population that claimed themselves as "vegetarians" suffered from SAD, while among the non-vegetarian participants, only 3.4% of them were SAD patients. The proportion of vegetarians in the SAD patients from

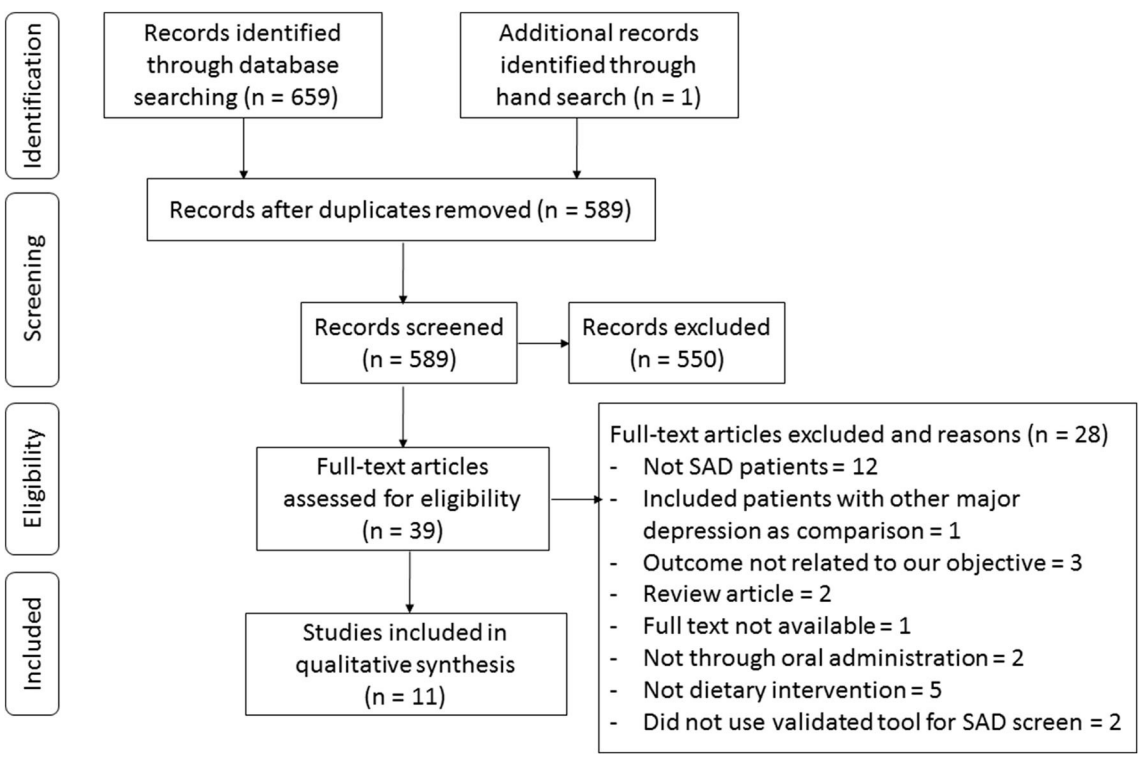

FIGURE 2 | Flowchart of study selection according to the PRISMA guideline.

TABLE 1 | Characteristics of included studies evaluating the associations between diet and SAD.

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
Meesters ANR, 2017, Finland (Study I)	Cross-sectional, SPAQ	4578, 52.1[a], 123	Vegan, FFQ	SAD severity, SPAQ	14.6% among vegetarians, and 3.4% among non-vegetarians	Vegetarian vs. non-Vegetarian	**OR = 3.9 (1.81–8.36)**	Being vegetarians is associated with higher possibility of developing SAD. However, logistic regression analysis revealed that none of the GSS item scores or the total GSS showed a significant relationship with vegetarianism.
				GSS, SPAQ	6.2 ± 3.6 for Vegetarians, and 5.2 ± 3.2 for non-Vegetarians	Vegetarian vs. non-Vegetarian	$p > 0.05$	
The Netherlands (Study II)	Cross-sectional, DSM-IV	257, 37.5, 257	Vegan, Asked by researchers whether being vegetarian	GSS, SPAQ	12.7 ± 4.4 for Vegetarians, and 13.5 ± 3.5 for non-Vegetarians	SAD vs. non-SAD	**OR = 1.5** ***p* < 0.05**	The logistic regression analysis showed a significant relationship between seasonal loss of energy and vegetarianism.
Morales-Muñoz I, 2017, Finland	Cross-sectional, SPAQ	8135, 55.7, 171	Alcoholism, M-CIDI	ADD, M-CIDI	0.08% for SAD patients, and 0.03% for control	Case vs. control	***p* < 0.001**	The one-way ANOVA analysis showed that compared with control, people with SAD showed greater possibilities in having alcohol use/dependence disorder in lifetime.
				AUD, M-CIDI	0.12% for SAD patients, and 0.06% for control	Case vs. control	***p* = 0.003**	
				Alcohol abuse during the past 12 months, M-CIDI	1.09% for SAD patients, and 1.02% for control	Case vs. control	***p* = 0.002**	
				ADD during the past 12 months, M-CIDI	0.03% for SAD patients, and 0.01% for control	Case vs. control	***p* = 0.032**	
				AUD during the past 12, M-CIDI	0.04% for SAD patients, and 0.01% for control	Case vs. control	***p* = 0.024**	
				Seasonal changes in sleep duration, SPAQ	NR	One unit change in ADD	***p* = 0.005**	Pearson correlation analysis showed that people diagnosed with ADD reported larger seasonal changes in sleep duration, social activity, energy, and mood; AUD patients reported larger seasonal changes in social activity and mood; patients suffered ADD past 12 months reported larger seasonal changes in sleep duration, social activity, energy, and mood; patients suffered AUD past 12 months reported larger seasonal changes in sleep duration, energy, and mood; and patients suffered alcohol abuse past 12 months reported larger seasonal changes in energy and mood.

(Continued)

TABLE 1 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Seasonal change in social activity, SPAQ	NR	One unit change in ADD	***p* = 0.007**	
				Seasonal changes in energy, SPAQ	NR	One unit change in ADD	***p* < 0.001**	
				Seasonal changes in mood, SPAQ	NR	One unit change in ADD	***p* < 0.001**	
				Seasonal changes in social activity, SPAQ	NR	One unit change in AUD	***p* = 0.007**	
				Seasonal changes in mood, SPAQ	NR	One unit change in AUD	***p* < 0.001**	
				Seasonal changes in sleep duration, SPAQ	NR	One unit change in ADD past 12 months	***p* = 0.004**	
				Seasonal change in social activity, SPAQ	NR	One unit change in ADD past 12 months	***p* = 0.003**	
				Seasonal changes in energy, SPAQ	NR	One unit change in ADD past 12 months	***p* = 0.013**	
				Seasonal changes in mood, SPAQ	NR	One unit change in ADD past 12 months	***p* < 0.001**	
				Seasonal changes in sleep duration	NR	One unit change in AUD past 12 months	***p* = 0.004**	
				Seasonal changes in energy	NR	One unit change in AUD past 12 months	***p* = 0.006**	
				Seasonal changes in mood	NR	One unit change in AUD past 12 months	***p* < 0.001**	
				Seasonal changes in energy	NR	One unit change in alcohol abuse past 12 months	***p* = 0.027**	
				Seasonal changes in mood	NR	One unit change in alcohol abuse past 12 months	***p* < 0.001**	
Krauchi K, 1987, Switzerland	Case-control, DSM-III	54, 40.7[a], 28	Food frequency, FDFQ	Starch-rich foods intake amount (portions/month), FDFQ	50.3 ± 15.1 for case, and 61.7 ± 15.5 for control	Case vs. Control	***p* < 0.05**	One-way ANOVA showed that compare with control, SAD patients had more preference of consuming starch and fiber-rich foods, but similar frequencies of taking sugar-rich foods, dairy-rich foods, protein-rich foods, and caffeine-containing beverages.

(Continued)

TABLE 1 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Fiber-rich foods intake amount (portions/month), FDFQ	61.6 ± 20.4 for case, and 82.8 ± 27.9 for control	Case vs. Control	***p* < 0.01**	
				Sugar-rich foods intake amount (portions/month), FDFQ	34.4 ± 20.3 for case, and 41.3 ± 15.7 for control	Case vs. Control	$p > 0.05$	
				Protein-rich foods intake amount (portions/month)	26.4 ± 12.7 for case, and 26.2 ± 9.8 for control	Case vs. Control	$p > 0.05$	
				Dairy intake amount (portions/month)	59.4 ± 29.1 for case, and 53.5 ± 27.1 for control	Case vs. Control	$p > 0.05$	
				alcohol intake amount (dl/month)	5.0 ± 3.7 for case, and 4.4 ± 4.7 for control	Case vs. Control	$p > 0.05$	
				Caffeine-containing drinks amount (portions/month)	70.7 ± 14.7 for case, and 80.2 ± 21.7 for control	Case vs. Control	$p > 0.05$	
				Seasonal variation of starch-rich foods intake, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	Two-way ANOVA for repeated measures analysis showed that there was no interaction between case vs. control and seasonality on seasonal variation of food item intake. However, significant seasonal variations were found in starch-rich foods and dairy products in cases.
				Seasonal variation of fiber-rich foods intake amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	
				Seasonal variation of sugar-rich foods intake amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	
				Seasonal variation of protein-rich foods intake amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	
				Seasonal variation of dairy intake amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	
				Seasonal variation of alcohol intake amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	
				Seasonal variation of caffeine-containing drinks amount, FDFQ	NA	(Case vs. Control) * Seasons	$p > 0.05$	

FFQ, Food Frequency Questionnaire; SPAQ, Seasonal Pattern Assessment Questionnaire; GSS, Global Seasonality Score; DSM, Diagnostic and Statistical manual of Mental disorders; M-CIDI, The World Health Organization Composite International Diagnostic Interview, the Munich version; ADD, Alcohol dependence disorder in lifetime; AUD, Alcohol use disorder in lifetime; SIGH-SAD, Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders; SCID, DSM-IV Structured Clinical Interview for Depression; NR, Not report; Underlined context, detailed data not shown in the publication; Bold text, Statistically significant.

[a]*Calculated according to the information provided.*

TABLE 2 | Characteristics of included studies evaluating the associations between eating behaviors and SAD.

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
Donofry SD, 2014, USA	Cross-sectional, DSM-IV-TR	112, 41.8, 112	Binge eating, QEWP-R	Binge eating, QEWP-R	26.5% among SAD patients	NA	NA	Logistic regression adjusting for age and gender showed that the spectrum of eating pathology in SAD patients involve binge eating
				Weekly binge eating, QEWP-R	11.6% among SAD patients	NA	NA	
				Binge eating defined by DSM-IV-TR, QEWP-R	8.9% among SAD patients	NA	NA	
				GSS, SPAQ	16.3 ± 3.6 for binge eating patients, and 14.9 ± 4.2 for non-clinical subjects	Binge eating patients vs. non-clinical subjects	OR = 1.057, $p = 0.40$	
Krauchi K, 1996, Switzerland	Case-control, Rosenthal criteria or DSM-III-R	164, NR, 84	Eating disorders, DEBQ	External eating, DEBQ	NR	Case vs. Control	**$p < 0.001$**	One-way ANOVA with Bonferroni adjustment showed that compared with normal control and stressful subjects (control II), SAD patients had higher tendency for 'external eating' (food intake steered by external stimuli) and 'emotional eating' (eating simulated by anxiety, insecurity, irritability, and depression), but similar 'restraint eating' (restrict food intake for weight control).
				Emotional eating, DEBQ	NR	Case vs. Control	**$p < 0.001$**	
				Restraint eating, DEBQ	NR	Case vs. Control	$p > 0.05$	
			Conditional food intake, Added questions to DEBQ	Consume sweets when depressed, Added questions to DEBQ	57.1% for case, and 13.2% for control	Case vs. Control	**$p < 0.05$**	One-way ANOVA with Bonferroni adjustment showed that compared with normal control and stressful subjects (control II), the percentage of consuming sweets when experiencing emotional eating (depression, anxiety, loneliness) was higher among SAD patients. Conditional food intake of other food items were similar between case and control during external eating and restraint eating.
				Consume starch when depressed, Added questions to DEBQ	17.9% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	

(Continued)

TABLE 2 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Consume fruits when depressed, Added questions to DEBQ	2.4% for case, and 0% for control	Case vs. Control	$p > 0.05$	
				Consume caffeine when depressed, Added questions to DEBQ	21.4% for case, and 21.1% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol when depressed, Added questions to DEBQ	14.3% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume dairy products when depressed, Added questions to DEBQ	11.9% for case, and 5.3% for control	Case vs. Control	$p > 0.05$	
				Consume sweets when anxious, Added questions to DEBQ	27.4% for case, and 5.3% for control	Case vs. Control	**$p < 0.05$**	
				Consume starch when anxious, Added questions to DEBQ	10.7% for case, and 0% for control	Case vs. Control	$p > 0.05$	
				Consume fruits when anxious, Added questions to DEBQ	3.6% for case, and 0% for control	Case vs. Control	$p > 0.05$	
				Consume caffeine when anxious, Added questions to DEBQ	8.3% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol when anxious, Added questions to DEBQ	16.7% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
				Consume dairy products when anxious, Added questions to DEBQ	9.5% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume sweets when lonely, Added questions to DEBQ	38.1% for case, and 7.9% for control	Case vs. Control	**$p < 0.05$**	

(Continued)

TABLE 2 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Consume starch when lonely, Added questions to DEBQ	9.5% for case, and 5.3% for control	Case vs. Control	$p > 0.05$	
				Consume fruits when lonely, Added questions to DEBQ	4.8% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume caffeine when lonely, Added questions to DEBQ	10.7% for case, and 7.9% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol when lonely, Added questions to DEBQ	14.3% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume dairy products when lonely, Added questions to DEBQ	7.1% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume sweets when bored, Added questions to DEBQ	20.2% for case, and 15.8% for control	Case vs. Control	$p > 0.05$	
				Consume starch when bored, Added questions to DEBQ	9.5% for case, and 7.9% for control	Case vs. Control	$p > 0.05$	
				Consume fruits when bored, Added questions to DEBQ	7.1% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
				Consume caffeine when bored, Added questions to DEBQ	10.7% for case, and 13.2% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol when bored, Added questions to DEBQ	6.0% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	

(Continued)

TABLE 2 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Consume dairy products when bored, Added questions to DEBQ	8.3% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume sweets during external eating, Added questions to DEBQ	22.6% for case, and 15.8% for control	Case vs. Control	$p > 0.05$	
				Consume starch during external eating, Added questions to DEBQ	6.0% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume crackers during external eating, Added questions to DEBQ	2.4% for case, and 0% for control	Case vs. Control	$p > 0.05$	
				Consume protein during external eating, Added questions to DEBQ	1.2% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume fruits during external eating	1.2% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume caffeine during external eating, Added questions to DEBQ	6.0% for case, and 13.2% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol during external eating, Added questions to DEBQ	14.3% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
				Consume dairy products during external eating, Added questions to DEBQ	2.4% for case, and 2.6% for control	Case vs. Control	$p > 0.05$	
				Consume sweets during restraint eating, Added questions to DEBQ	53.6% for case, and 42.1% for control	Case vs. Control	$p > 0.05$	

(Continued)

TABLE 2 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Consume starch during restraint eating, Added questions to DEBQ	33.3% for case, and 15.8% for control	Case vs. Control	$p > 0.05$	
				Consume protein during restraint eating, Added questions to DEBQ	7.1% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
				Consume fat during restraint eating, Added questions to DEBQ	19.0% for case, and 23.7% for control	Case vs. Control	$p > 0.05$	
				Consume alcohol during restraint eating, Added questions to DEBQ	6.0% for case, and 10.5% for control	Case vs. Control	$p > 0.05$	
Berman K, 1993, Canada	Case-control, DSM-III-R	60, 32.8[a], 30	Dysfunctional eating, EDI	Bulimia, EDI	3.3 ± 4.2 for case, and 0.9 ± 1.9 for control	Case vs. Control	**$p < 0.05$**	*post hoc* student-newman-keuls tests for pairwise comparisons (case vs. control vs. bulimia nervosa patients) showed more severe bulimia disorders in SAD patients compared to non-clinical subjects.
Krauchi K, 1987, Switzerland	Case-control, DSM-III	54, 40.7[a], 28	Food frequency, FDFQ	Breakfast in weekdays (meal/month), FDFQ	21.0 ± 5.1 for case, and 15.4 ± 9.6 for control	Case vs. Control	**$p < 0.05$**	One-way ANOVA showed that compare with control, SAD patients consumed significantly more dinners and evening snacks during weekdays and weekends.
				Morning snacks in weekdays (meal/month), FDFQ	6.1 ± 6.5 for case, and 6.7 ± 7.2 for control	Case vs. Control	$p > 0.05$	
				Lunch in weekdays (meal/month), FDFQ	20.5 ± 6.2 for case, and 21.1 ± 3.6 for control	Case vs. Control	$p > 0.05$	
				Afternoon snacks in weekdays (meal/month), FDFQ	8.7 ± 7.0 for case, and 6.1 ± 6.6 for control	Case vs. Control	$p > 0.05$	

(Continued)

TABLE 2 | Continued

First author, year, country	Study design, SAD screen tool	Total subjects, age (mean), Patients N	Diet, diet assessment tool	Outcome, outcome assessment tool	Means/ frequencies	Comparison	OR (CI) or *p* values	Conclusion
				Dinner in weekdays (meal/month), FDFQ	22.7 ± 3.7 for case, and 21.1 ± 4.0 for control	Case vs. Control	***p* < 0.05**	
				Evening snacks in weekdays (meal/month), FDFQ	8.6 ± 7.5 for case, and 2.9 ± 3.7 for control	Case vs. Control	***p* < 0.001**	
				Breakfast in weekends (meal/month), FDFQ	2.1 ± 1.6 for case, and 1.8 ± 1.5 for control	Case vs. Control	$p > 0.05$	
				Morning snacks in weekends (meal/month), FDFQ	0.1 ± 0.4 for case, and 0.2 ± 0.5 for control	Case vs. Control	$p > 0.05$	
				Brunch in weekends (meal/month), FDFQ	2.0 ± 1.5 for case, and 1.7 ± 1.4 for control	Case vs. Control	$p > 0.05$	
				Lunch in weekends (meal/month), FDFQ	1.4 ± 1.5 for case, and 1.6 ± 1.4 for control	Case vs. Control	$p > 0.05$	
				Afternoon snacks in weekends (meal/month), FDFQ	1.7 ± 1.2 for case, and 1.2 ± 1.0 for control	Case vs. Control	$p > 0.05$	
				Dinner in weekends (meal/month), FDFQ	3.8 ± 0.5 for case, and 3.4 ± 0.7 for control	Case vs. Control	***p* < 0.01**	
				Evening snacks in weekends (meal/month), FDFQ	1.3 ± 1.4 for case, and 0.5 ± 0.5 for control	Case vs. Control	***p* < 0.05**	

DSM, Diagnostic and Statistical manual of Mental disorders; QEWP-R, Questionnaire on Eating and Weight Patterns-Revised; DEBQ, Dutch Eating Behavior Questionnaire; SPAQ, Seasonal Pattern Assessment Questionnaire; GSS, Global Seasonality Score; SCID, DSM-IV Structured Clinical Interview for Depression; FDFQ, Food/Drink Frequency Questionnaire; EDI, Eating Disorders Inventory; NA, Not available; NR, Not report; Bold text, Statistically significant.
[a]*Calculated according to the information provided.*

TABLE 3 | Characteristics of included studies evaluating the associations between nutrition intervention and SAD.

First author, year, country	Study design, SAD screen tool	Total N, age (mean)	Interv, dosage/d, duration	Ctrl	Interv N	Ctrl N	Outcome, outcome assessment tool	(Mean ± SD)/frequency in interv group	(Mean ± SD)/frequencies in ctrl group	Compare, *p*-values	Conclusion
Frandsen TB, 2014, Denmark	RCT, SPAQ	43, 44.2	Vitamin D, 70 μg, 3 months	Placebo	22	21	Depression severity, SIGH-SAD	−6.4 ± 3.3*	−6.8 ± 9.5*	Interv vs. ctrl, $p = 0.7$	One-way ANOVA analysis showed that compared with the control group, vitamin D supplementation presented no effect in impeding SAD.
Mischoulon D, 2010, USA	RCT, crossover, SCID	18, 43	High carb[a] for phase I and ctrl[b] for phase II, Twice, 12 days for each phase	Ctrl[b] for phase I and high carb[a] for phase II	10	8	Depression severity, Hamilton-D-28 scale	6.5 ± 3.8 at the end of phase I, and 4.6 ± 3.9 at the end of phase II	9.3 ± 4.4 at the end of phase I, and 7.9 ± 5.3 at the end of phase II	Interv vs. ctrl, $p = 0.09$	Repeated measure ANOVA showed that the high-carbohydrate mix group did not significantly decrease depression symptom or remission compared with the control group.
							Remission rates, Hamilton-D-28 scale	50% at the end of phase I, and 88% at the end of phase II	38% at the end of phase I, and 50% at the end of phase II	Interv vs. ctrl, $p = 0.66$ at the end of phase I, and $p = 0.28$ at the end of phase II	
	RCT, SCID	32, 46	High carb[c], Twice, 21 days	ctrl[b]	15	17	Depression severity, Hamilton-D-28 scale	6.4 ± 5.8	6.1 ± 4.4	Interv vs. ctrl, $p = 0.88$	Repeated measure ANOVA showed that the high-carbohydrate mix group did not significantly decrease depression symptom or remission compared with the control group.
							Remission rates, Hamilton-D-28 scale	71%	71%	Interv vs. ctrl, $p = 1$	
Danilenko KV, 2008, Russia	RCT, DSM-IV	22, 37.8	High carb (morning), NA, 9 days	NA	9	NA	Depression severity, SIGH-SAD	NR	NR	[High carb (morning) vs. high carb (evening) vs. high protein] × time, $p = 0.61$	Repeated measure ANOVA showed that no differential effects of diet on depression were found between high carb diet vs. high protein diet. However, participants from all groups had an improved SIGH-SAD score.
			High carb (evening), NA, 9 days	NA	6	NA					
			High protein, NA, 9 days	NA	7	NA					

(Continued)

TABLE 3 | Continued

First author, year, country	Study design, SAD screen tool	Total N, age (mean)	Interv, dosage/d, duration	Ctrl	Interv N	Ctrl N	Outcome, outcome assessment tool	(Mean ± SD)/frequency in interv group	(Mean ± SD)/frequencies in ctrl group	Compare, *p*-values	Conclusion
							Emotional eating, DEBQ	NR	NR	[High carb (morning) vs. high carb (evening) vs. high protein] × time, ***p* = 0.014**	Repeated measure ANOVA revealed that subjects' ratings of the 'emotional' factor increased after the CHO-morning diet, decreased after the CHO-evening diet, and remained unchanged after the high-protein diet. Diet significantly affected subjects' eating behavior, and such impact was affected by time. Ratings of restrained and external eating factors were similar before and after the diets, and there was no significant difference among meal groups.
							External eating, DEBQ	NR	NR	[High carb (morning) vs. high carb (evening) vs. high protein] × time, $p > 0.05$	
							Restraint eating, DEBQ	NR	NR	[High carb (morning) vs. high carb (evening) vs. high protein] × time, $p > 0.05$	
Oren DA, 1994, USA	RCT, DSM-III-R	27, 48	Vitamin B12, 4.5 mg, 2 weeks	Placebo	14	13	Depression severity, SIGH-SAD	18 ± 8	21 ± 10	Interv vs. ctrl, $p > 0.25$	Repeated measure ANOVCA showed that cyanocobalamin supplementation did not change SIGH-SAD rating scores between interventional group and control group.

(Continued)

TABLE 3 | Continued

First author, year, country	Study design, SAD screen tool	Total N, age (mean)	Interv, dosage/d, duration	Ctrl	Interv N	Ctrl N	Outcome, outcome assessment tool	(Mean ± SD)/frequency in interv group	(Mean ± SD)/frequencies in ctrl group	Compare, *p*-values	Conclusion
Rosenthal NE, 1988, USA	RCT, crossover, DSM-III	32 (16 SAD patients and 16 non-clinical subjects), 40	High carb diet[b] follows High protein diet (sequence 1), NA, one-time intervention	High protein diet[c] follows High carb diet (sequence 2)	16	16	Tension, POMS	NR	NR	Meal (carb vs. prot) x sequence, ***p* < 0.04**	Repeated measure ANOVA showed that the high-carb meal significantly decreased tension, depression, and anger scores, whereas the protein-rich meal had the opposite effect. The effect of the meals was affected by sequence. Fatigue values increased following the protein-rich meal in both patients and controls. High carb diet decreased fatigue in patients but not in control. Vigor declined in the first 2 h after both meals, but the decline was less marked in the SAD group than in normal controls after high carb diet.
							Depression, POMS	NR	NR	Meal x sequence, ***p* < 0.02**	
							Anger, POMS	NR	NR	Meal x sequence, ***p* < 0.05**	
							Fatigue, POMS	NR	NR	Meal x group (SAD vs. ctrl) x time, ***p* < 0.02**	
							Vigor, POMS	NR	NR	Diet x sequence, ***p* < 0.05**	

Interv, intervention; Ctrl, control; FFQ, Food Frequency Questionnaire; SPAQ, Seasonal Pattern Assessment Questionnaire; GSS, Global Seasonality Score; DSM, Diagnostic and Statistical manual of Mental disorders; M-CIDI, The World Health Organization Composite International Diagnostic Interview, the Munich version; ADD, Alcohol dependence disorder in lifetime; AUD, Alcohol use disorder in lifetime; SIGH-SAD, Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders; SCID, DSM-IV Structured Clinical Interview for Depression; NR, Not report; Underscored context, detailed data not shown; Bold text, Statistically significant.

[*] *Mean of difference ± SD.*

[a] *40 grams of a mixture of potato starch, maltodextrin, dextrose, and dextrin.*

[b] *Carbohydrate-protein mix consisting of 15 g milk protein casein and 25 g carbohydrate mixture.*

[c] *Contains 105 g of carbohydrate, 0.7 g of protein, and 42.7 g of fat.*

[d] *Contains 105 g of protein, 15 g of carbohydrates, and 33.3 of fat.*

the Dutch SAD outpatient clinic dataset was 12.5%, which was higher than that in the general population (4.5%). However, the association between being vegetarian and experiencing a loss of energy was not consistent in Finland vs. the Netherlands.

Alcoholism

Two studies assessed alcohol drinking among SAD patients vs. the control population (Krauchi and Wirz-Justice, 1988; Morales-Munoz et al., 2017). One population-based, cross-sectional study showed that, compared with the control, people with SAD showed greater possibilities of having alcohol dependence in their lifetime, represented by a higher prevalence of alcohol dependence disorder in their lifetime, alcohol use disorder (AUD) in their lifetime, alcohol abuse during the past 12 months, alcohol dependence disorder during the past 12 months, or AUD during the past 12 months (Morales-Munoz et al., 2017). It is important to note that the DSM-5 changed from differentiating between alcohol abuse and alcohol dependence to a single category of AUD, which is defined as alcohol often being taken in larger amounts or over a longer period than intended. By further exploring the relationship between alcoholism and Global Seasonality Score items, the researchers found that people with comorbid alcohol abuse showed larger seasonal changes in sleep duration, social activity, energy, and mood, which implicated a greater severity of seasonal complaints. No significant association between alcohol abuse and seasonal weight or appetite changes was found in this study. On the contrary, one case-control reported comparable alcohol consumption amounts between the SAD patients and the control subjects, and seasonality variation was not observed in alcohol consumption among SAD patients (Krauchi and Wirz-Justice, 1988).

Food Intake Frequency

Food intake frequency in SAD was reported by one case-control study (Krauchi and Wirz-Justice, 1988). Krauchi et al. reported that, compared to the control, SAD patients have more preference for consuming starch and fiber-rich foods but similar frequencies of taking sugar-rich foods, dairy-rich foods, protein-rich foods, and caffeine-containing beverages. Furthermore, the researchers found that, in comparison to controls, SAD subjects showed a significantly increased starch-rich food score in all seasons except summer ($p < 0.05$) and a minimal dairy product intake in winter, compared to all other seasons ($p < 0.01$). Exploring the seasonal variation of food consumption further showed that there was no interaction between case vs. control and seasonality on seasonal variation of food item intake. However, significant seasonal variations were found in starch-rich foods and dairy products in SAD patients.

Eating Behavior and SAD

Binge Eating and Restraint Eating

One cross-sectional study examined the frequency of binge eating among SAD patients using a food and drink frequency questionnaire (Donofry et al., 2014). This study showed that 26.5% of the subjects with SAD self-reported episodic overeating with a loss of control, 11.6% had weekly binge eating, and 8.9% had binge eating defined by the DSM-IV-TR. "Restraint" eating is based on the tendency to restrict food consumption to maintain body weight or to promote weight loss, such as with anorexia nervosa (Wardle, 1987). One case-control study reported that the difference in the restraint eating factor scores between SAD patients and control was insignificant (Krauchi et al., 1997). By leveraging the Eating Disorders Inventory, one case-control study revealed significantly more severe bulimia nervosa, which is an eating disorder characterized by a cycle of binging and compensatory behaviors exemplified by self-induced vomiting (Castillo and Weiselberg, 2017) in SAD patients compared to non-clinical subjects (Berman et al., 1993).

External Eating and Emotional Eating

External eating refers to whether persons eat more than normal under the situations of external stimuli: the sight, smell, amount, and availability of food; the time-of-day signal or the lack of clearly recognized internal signals of hunger and satiation (Nisbett, 1968; Schachter and Gross, 1968; Nisbett and Kanouse, 1969). Emotional eating manifests itself through increased eating under the situations or emotions of anxiety, insecurity, irritability, or depression (Bruch, 1961). To investigate the eating style of SAD patients, Krauchi et al. conducted a case-control study and found that SAD patients had higher frequencies of external eating and emotional eating (Krauchi et al., 1997). In addition, the researchers reported that, when encountering depression, anxiety, and loneliness, SAD subjects had a higher tendency to consume sweets than normal controls. However, the frequency of consuming starch, fruits, caffeine, alcohol, and dairy was comparable between case and control under external and emotional situations.

Meal Frequency

One case-control study reported meal frequency within different time frames in either weekdays or weekends by recruiting 28 SAD patients and 26 controls (Krauchi and Wirz-Justice, 1988). Data showed that SAD patients consumed significantly larger dinners and more evening snacks during weekdays and weekends, while the frequencies of morning snack, lunch, and afternoon snack intake on both weekdays and weekends and brunch intake on weekends were similar between case and control.

Nutrition Intervention and SAD

Vitamin D

One RCT reported the efficacy of vitamin D supplementation in SAD patients (Frandsen et al., 2014). The participants were randomized to either 70 μg of vitamin D or placebo for 12 weeks during the winter period. At the end of the intervention, there were no significant between-group differences in the sum of the self-reported questionnaire, the Structured Interview Guide for the Hamilton Depression Rating Scale, and Seasonal Affective Disorders (SIGH-SAD).

Vitamin B12

The treatment effect of vitamin B12 (cyanocobalamin) for SAD symptoms was reported in one RCT (Oren et al., 1994). After supplementing the interventional group with vitamin B12 for 2 weeks, the study did not observe any significant difference in

SIGH-SAD rating scores between the interventional group and the control group.

Macronutrients

Three RCTs examined the impact of oral carbohydrate administration in individuals with SAD (Rosenthal et al., 1989; Danilenko et al., 2008; Mischoulon et al., 2010). One crossover RCT recruited both SAD patients and normal controls into the study and randomly provided all of the participants either a carbohydrate-rich diet followed by a protein-rich diet (sequence 1) or a protein-rich diet followed by a high-carb diet (sequence 2) (Rosenthal et al., 1989). Results showed that the high-carb meal significantly decreased tension, depression, and anger scores, whereas the protein-rich meal had the opposite effect. The effect of the meals on tension, depression, and anger was affected by sequence. Fatigue values increased following the protein-rich meal in both patients and controls. The high-carb diet decreased fatigue in patients but not in the control. Vigor declined in the first 2 h after both meals, but the decline was less marked in the SAD group than in normal controls after the high-carb diet. Such results were not in line with the findings from another two RCTs, which reported insignificant effects of high-carb diet administration on SAD severity or remission among subjects with SAD symptoms (Danilenko et al., 2008; Mischoulon et al., 2010).

In addition, Danilenko et al. separated the carbohydrate-rich diet into two different time frames, morning and evening, and compared the role of the high-carb (morning) and high-carb (evening) diets with a high-protein diet in SAD progression. Although the amelioration of SAD severity between diet groups was statistically insignificant, the researchers found distinctively altered eating behavior in different groups. Subjects' ratings of the "emotional" factor increased after the carb-morning diet, decreased after the carb-evening diet, and remained unchanged after the high-protein diet, and the impact of diet was affected by time. The emotional factor is constructed from a questionnaire with 13 questions expressing the desire to eat following negative emotions. Ratings of restrained and external eating factors were similar before and after the diets, and there was no significant difference among meal groups (Danilenko et al., 2008).

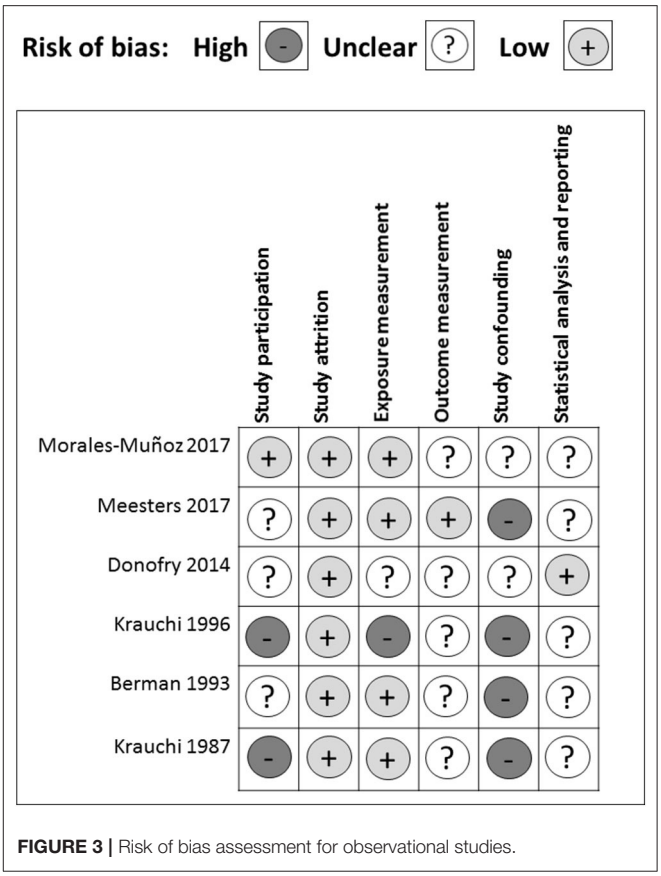

FIGURE 3 | Risk of bias assessment for observational studies.

Methodological Quality

There were several common sources of bias in the included studies, which are presented in **Figures 3**, **4**. Since the risk of bias in certain domains (such as selection bias) was different between observational studies and clinical trials, we utilized different tools for bias assessment, and thus, the bias of these studies was reported separately.

Observational Studies

All of the cross-sectional and case-control studies presented several risks of bias in one or more domains. In the study participation domain, only one study achieved a low risk of bias, while 50% (3/6) had a medium risk and 33% (2/6) had a high risk of bias (**Figure 3**). Specifically, three studies did not enroll adequate participants (Berman et al., 1993; Krauchi et al., 1997; Donofry et al., 2014). One study did not provide descriptions of the source population (Krauchi and Wirz-Justice, 1988). Two studies did not report a detailed period or place of recruitment (Krauchi et al., 1997; Donofry et al., 2014), and three studies did not provide clear inclusion and exclusion criteria (Krauchi and Wirz-Justice, 1988; Berman et al., 1993; Krauchi et al., 1997). Only one study provided an adequate description of the sampling frame and recruitment (Morales-Munoz et al., 2017), and all of the studies reported details of the baseline study sample. Overall, the observational studies included in this systematic review had a low bias in the study attrition domain since either no, or only short-period, follow-ups were required throughout the study.

Four out of six studies acquired a low risk of bias in the exposure measurement domain. One had a medium risk, and one had a high risk of bias. All of the studies but one (Krauchi et al., 1997) provided a clear definition of prognostic factor. Two studies did not employ valid prognostic factor measurement (Krauchi and Wirz-Justice, 1988; Donofry et al., 2014). Four studies only presented categorical prognostic factor data or did not articulate the cut-off points of their continuous variables (Krauchi and Wirz-Justice, 1988; Krauchi et al., 1997; Donofry et al., 2014; Meesters et al., 2016). Only one study stated that the method of prognostic factor measurement was not the same for all study participants, and the proportion of the study sample that completed data for prognostic factors was inadequate (Krauchi et al., 1997).

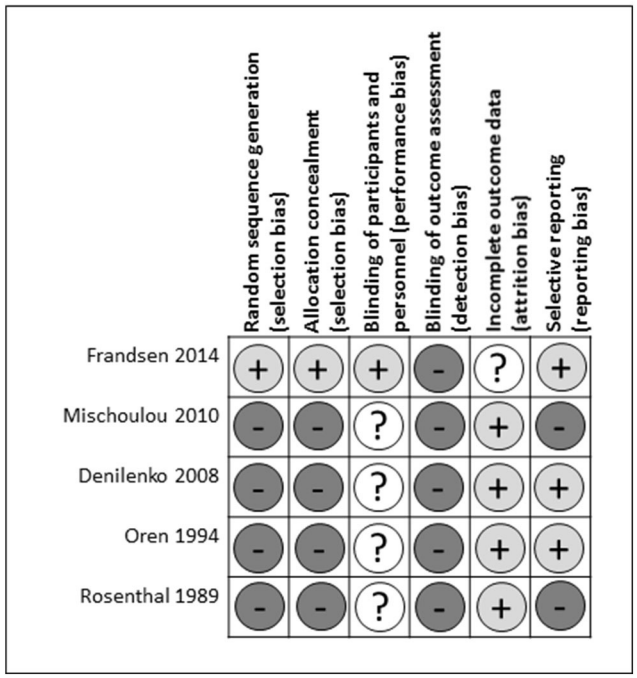

FIGURE 4 | Risk of bias assessment for RCTs.

In the outcome measurement domain, only one study had a low risk of bias, while the other five studies presented a medium risk of bias, which resulted from an unclear definition of outcome (Krauchi and Wirz-Justice, 1988; Morales-Munoz et al., 2017), inadequately valid outcome measurement methods (Krauchi and Wirz-Justice, 1988; Kurlansik and Ibay, 2012; Donofry et al., 2014), and inconsistent outcome measurements for each study participant (Berman et al., 1993). Since most studies used analysis of variance and did not perform correlation analysis (Krauchi and Wirz-Justice, 1988; Berman et al., 1993; Krauchi et al., 1997; Meesters et al., 2016), they did not adjust for potential confounders. For the two studies that used logistic regression to explore the relationship between prognostic factors and SAD severity, Donofry et al. adjusted for age and gender (Donofry et al., 2014), while Meesters et al. adjusted for age and gender in the Dutch data, and only gender in the Finnish data (Meesters et al., 2016). Thus, in the study-confounding domain, two studies had a medium risk of bias, whereas all of the other studies had a high risk of bias.

In the statistical analysis and reporting domain, one study was evaluated as having a low risk of bias, while the others had a medium risk of bias, mostly resulting from an insufficient strategy of model planning (Krauchi and Wirz-Justice, 1988; Berman et al., 1993; Krauchi et al., 1997; Meesters et al., 2016), and an inadequate statistical model for the design of the study (Krauchi and Wirz-Justice, 1988; Berman et al., 1993; Krauchi et al., 1997; Donofry et al., 2014; Meesters et al., 2016; Morales-Munoz et al., 2017). One study was subjected to reporting bias due to the incomplete presentation of study results (Morales-Munoz et al., 2017). In addition, all of the cross-sectional and case-control studies used questionnaires retrospectively because of the nature and characteristics of observational studies and, may, therefore, have been influenced by recall bias.

RCTs

Out of five RCTs, only one study reported a detailed method of random sequence generation and allocation concealment (Frandsen et al., 2014) leaving four studies at high risk of selection bias (Rosenthal et al., 1989; Oren et al., 1994; Danilenko et al., 2008; Mischoulon et al., 2010) (**Figure 4**). One study articulated the process of blinding participants and personnel (Frandsen et al., 2014), while the others only stated that they had double-blinded the subjects (Rosenthal et al., 1989; Oren et al., 1994; Danilenko et al., 2008; Mischoulon et al., 2010) resulting in one study having a low risk and four studies a high risk of performance bias. None of the studies provided detailed descriptions of the blinding of outcome assessment, leading to a high risk of detection bias among five studies. In the attrition bias domain, four out of five studies had a low risk of bias, while one study had a medium risk of bias resulting from incomplete outcome data (Frandsen et al., 2014). In the selective reporting domain, three studies had a low risk of bias, while two studies were scored as having a high risk of bias with missing appetite or food craving data (Mischoulon et al., 2010), and missing between-group analysis for tension, depression, and anger (Rosenthal et al., 1989).

DISCUSSION

Overall, there is lacking evidence that diet, eating behavior, and nutrition intervention influence the development of SAD. The observational studies, including one for vegetarianism; two for alcoholism; one for food intake frequency; two for binge eating, restraint eating, external eating, and emotional eating; and one for meal frequency, revealed some distinctive dietary and behavioral patterns in SAD patients, however. Among the five RCTs, three studies reported inconsistent efficacy of carbohydrate-rich diets in improving SAD symptoms, and the two other studies found no evidence of an association between vitamin D supplementation or vitamin B12 supplementation and SAD. Nevertheless, given the methodological limitations of the studies and the inadequacy of publications on this topic, the lack of evidence does not necessarily imply the absence of true associations. We did not conduct a meta-analysis due to the heterogeneity of the studies. However, this review is the most current synthesis of the evidence revealing the role of diet, eating behavior, and nutrition intervention in SAD patients.

In the study by Meesters et al., the percentage of vegetarians that suffered from SAD in Finland was four times higher than the percentage of people with SAD symptoms in the control population. The percentage of vegetarian SAD patients in the Netherlands dataset was three times higher than that of

vegetarians in the control population (Meesters et al., 2016). These findings were consistent with the report from three other observational research works showing that vegetarians had higher depression scores, on average, than non-vegetarians (Baines et al., 2007; Michalak et al., 2012; Hibbeln et al., 2018). Several possible factors previously linked to an augmented risk of depressive symptoms might underlie the increased risk of depression among vegetarians, including the inadequate intake of multiple interactive nutrients that might be lacking in vegetarian diets. L-tryptophan, for example, is abundant in animal-sourced protein and is a vital nutrient for serotonin synthesis in the brain (Lambert et al., 2002). Endogenous serotonin is one of the major monoamine transmitters implicated in mood disorders (Gupta et al., 2013). Any disruption in the synthesis, metabolism, or uptake of serotonin has been found to be partly responsible for certain manifestations of depression, such as fatigue (Meeusen et al., 2006). However, Meesters et al. found a significant association between the seasonal loss of energy and vegetarianism only in the Dutch dataset and not in the Finnish data. This might be because, in both datasets, the question about special diet adherence was based on self-reported questionnaires and could be subjected to misinterpretation. Additionally, since the patients retrospectively recalled the diet, recall bias may also have occurred.

Two studies attained inconsistent conclusions on the relationship between alcohol consumption and SAD (Krauchi and Wirz-Justice, 1988; Morales-Munoz et al., 2017). Such a disparity might be due to the different definitions of exposure (alcoholism vs. alcohol intake) and the different food questionnaires used in the studies. One systematic review and meta-analysis explored the link between AUD and major depression, showing that the presence of either disorder doubled the risks of the other disorder, with pooled, adjusted odds ratios ranging from 2.00 to 2.09 (Boden and Fergusson, 2011). Since AUD plays a critical role in the etiology of depression, considering the effects of alcohol abuse on individuals' social, economic, and legal circumstances, they further stated that AUD causing major depression was the most plausible causal association between AUD and major depression, not vice versa. However, it is entirely possible that alcohol is used as a coping mechanism for the development of depressive symptoms. Notably, Rosenthal et al. did not observe a significant association between alcohol intake and SAD. This was probably because they included participants with average alcohol intake at 4.4–5.0 dl/month and did not report any case of repetitive problems with alcohol at the social, interpersonal, legal, and occupational levels. Therefore, it is possible that normal alcohol consumption was not associated with SAD development, but hazardous alcohol intake imposes a negative impact on SAD.

It has been reported that atypical symptoms of depression, such as hyperphagia and weight gain, are frequently associated with SAD. Emotional eating has often been suggested to be one mechanism linking depression and subsequent development of obesity (Konttinen et al., 2019). Indeed, three included studies found that binge eating, restraint eating, emotional eating, and external eating were frequently observed in subjects with SAD symptoms (Berman et al., 1993; Krauchi et al., 1997; Donofry et al., 2014). Such data was in line with the report from a large cross-sectional study from 1,060 remitted depression patients, 309 currently depressed patients, and 381 healthy controls in the Netherlands. They found that remitted and current depressive disorders were significantly associated with more emotional eating ($p < 0.001$) and more external eating ($p < 0.001$) in a dose-response fashion (Paans et al., 2018), although Rosenthal et al. reported that eating style did not alter with a depressive state (SAD before and after light treatment) or seasonal variation (winter vs. summer). Furthermore, their finding that only emotional eating remains significant when adding external eating to the regression, but not the other way around, suggests that treatment against affect regulation problems, exemplified by emotional eating, and coaching patients to acquire better emotion regulation skills may possibly diminish SAD and its adverse health consequences.

To explore the efficacy of nutrition supplementation against SAD, we included two RCTs that gave SAD participants either vitamin D or vitamin B12 for potential SAD treatment, but neither of them showed significant beneficial effects in ameliorating SAD symptoms. In the country where the vitamin D supplementation RCT was performed, suboptimal 25-hydroxyvitamin D [25(OH)D] status is common (Frandsen et al., 2014). It has been anticipated that clinical trial participants with known symptoms of SAD would develop vitamin D insufficiency during wintertime and, thereby, benefit from vitamin D supplementation. One underlying reason why the study failed to observe a significant difference might be because the design did not favor inclusion of participants with lower 25(OH)D, so the study did not allow an investigation of the ability of vitamin D to improve mood in those with low 25(OH)D at baseline. In addition, this study selected a SPAQ-SAD cut-off of 8 to include more SAD participants, and such a score was less severe than that recommended by Kasper et al. (1989), which also reduced the possibility of observing a statistically significant difference. Nevertheless, such a result was in line with a large controlled clinical trial with 2,117 women that were given either 800 IU of vitamin D with 1,000 mg of calcium or placebo for 6 months. Results showed that the mental component score that reflected participants' subjective psychological well-being was not significantly different in the placebo group, indicating that supplementing women daily with a combination of vitamin D and calcium was not effective in promoting mental health or preventing wintertime blues (Dumville et al., 2006). Interestingly, another small RCT with 44 healthy subjects reported that giving subjects 400 or 800 IU of vitamin D3 per day significantly enhanced subjects' Positive Affect scores (enthusiastic, interested, and determined) but did not affect their Negative Affect scores (scared, afraid, and upset) (Lansdowne and Provost, 1998). One possible explanation for the disparity between this study and the previous two trials lies in the different vitamin D forms used as supplementation. Lansdowne et al. used vitamin D3, while the previous two studies employed vitamin D2. According to a meta-analysis of RCTs, supplementation with vitamin D3 imposes a significant and positive effect in the

raising of serum 25(OH)D concentrations compared to the effect of vitamin D2, indicating that vitamin D3 is more efficacious and could potentially become the preferred choice for vitamin D supplementation (Tripkovic et al., 2012). We should also not neglect the fact that, in the study by Lansdowne et al., they only observed a significant improvement in participants' scores in Positive Affective, which are positive emotions, but the scores in Negative Affective remained unchanged. This raises the possibility that vitamin D supplementation is effective only in promoting optimistic feelings but not in alleviating negative emotions such as depression, especially in a population that does not have vitamin D deficiency.

Cobalamin, one of the active vitamin B_{12} forms, plays a key role in neural health (Thakkar and Billa, 2015; Li et al., 2016). A deficiency status of cobalamin would inhibit the physiological formation of the myelin sheath, subsequently altering correct nerve transmission (Rizzo et al., 2016) leading to impaired memory function and cognition and depression (Mikkelsen et al., 2016). However, in the study by Oren et al., the treatment with vitamin B_{12} was ineffective in SAD patients. This could also be due to the inclusion of participants with adequate vitamin B_{12} at baseline. Plasma vitamin B_{12} levels of the participants were 447 $\pm$ 164 pg/ml, which is within the reference range for the laboratory at 200–900 pg/ml. Another limitation of this study was the short interventional period. However, a 2-week trial of light therapy for SAD was proven to be sufficient and effective (Avery et al., 2001), which indicates that vitamin B_{12} supplementation might not be as effective as other treatment strategies, such as light therapy. Another factor that might lessen the effect of vitamin B_{12} supplementation to null was the large placebo effect observed in the study, which obligates the treatment effect to be very robust in order to show a statistical difference between placebo and intervention. Furthermore, it should be noted that the vitamins folic acid, B_{12}, B_6, and B_2 jointly participate in one-carbon metabolism, in which methionine, from methyl-tetrahydrofolate reduction, is converted to S-adenosylmethionine, a universal donor of methyl groups, involving DNA, RNA, hormones, neurotransmitters, and others (Selhub, 2002). Because of these functions, one-carbon metabolism has drawn attention from researchers in preventing or treating diverse diseases including depression (Sugden, 2006; Assies and Pouwer, 2008; Baek et al., 2013; Assies et al., 2014; de Vries et al., 2015). Considering the synergistic effect of the vitamin B group in modulating biological and physiological responses, it warrants further investigation of how the vitamin B group, instead of single vitamin B_{12} supplementation, plays a role against SAD.

In the study by Krauchi et al., they raised the possibility that adjusting the percentage of macronutrients in SAD patients' diets may lead to certain therapeutic effects (Krauchi and Wirz-Justice, 1988). Nevertheless, the three RCTs that aimed to explore the impact of carbohydrate administration in SAD patients obtained different results (Rosenthal et al., 1989; Danilenko et al., 2008; Mischoulon et al., 2010). Results from Rosenthal's study were diverted between SAD patients and non-clinical subjects (Rosenthal et al., 1989). It has been hypothesized that the carbohydrate craving and increased carbohydrate consumption in SAD patients might be exerting their transient therapeutic effects by acting on serotonergic systems. However, SAD patients exhibited faster post-glucose glycemic and insulin responses and increased hedonic ratings of high concentrated sucrose solutions with depressive emotions than under euthymic situations (Krauchi et al., 1999). This might lead to a vicious cycle whereby the over-ingestion of carbohydrates may lower circulating glucose to subnormal levels after the surge of insulin, subsequently triggering elevated carbohydrate cravings and consumption. On the other hand, two other studies found no significant statistical differences in antidepressant effects between short-term carbohydrate or placebo in SAD patients (Danilenko et al., 2008; Mischoulon et al., 2010), although carbohydrate-heavy meals reduced evening hunger compared to the placebo meal (Mischoulon et al., 2010). These two studies are limited by small numbers of subjects and relatively short durations of intervention. With the combination of two independent studies, it also raises the possibility of dissimilar treatment conditions and ungeneralizable conclusions (Mischoulon et al., 2010).

Given the insufficient evidence showing beneficial efficacy of single nutrient supplementation or single diet intervention against SAD, it is entirely possible that providing only nutrient supplementation is not sufficient to mitigate the disease, while a combination of nutritional intervention, pharmacological therapy, and light therapy may augment the treating effect against SAD (Oren et al., 1994; Penders et al., 2016; Cools et al., 2018). Additionally, the RCTs included in this systematic review only provided SAD subjects with supplementation of a single nutrient or diet intervention with a fixed macronutrient percentage. Since the alteration of mood and sense of depression could be a consequence of several biological changes or resulting from various hormonal and nutritional cues (Kurlansik and Ibay, 2012), supplementation with a mix of nutrients will possibly lead to more beneficial results. In addition to vitamin B12 and vitamin D, anti-depression effects were observed in the controlled clinical trials with some other nutrients such as n-3 polyunsaturated fatty acids, zinc, and inositol (Mukai et al., 2014; Deacon et al., 2017; Schefft et al., 2017), which makes combination therapy of multiple nutrients, or interventions with dietary patterns and whole foods, seem logical, as they work in synergy with and function as the elements of the human biological network (Tapsell et al., 2016; Li et al., 2017, 2018).

However, it should be noted that there are several limitations to our current work. Only English-language papers were included in the current review, which limits our ability to incorporate evidence shown in other languages that might be relevant. In addition, this review only included published studies, which may have introduced publication bias since studies with negative results were less likely to be reported. The studies included in this systematic review were carried out using diverse methods (i.e., different SAD screening tools and different ways of performing statistical analysis), which raises challenges for homogenizing conclusions. Therefore, additional studies investigating diet, eating behavior, and nutrition intervention on SAD symptoms

are warranted for a systematic review with more complexity and homogeneity.

CONCLUSION

All RCTs reviewed in the current work are lacking in sample size or good study design. For observational studies, an enhanced strategy of statistical model building should be established. Additionally, results need to be replicated in double-blinded RCTs with larger populations and longer durations before any conclusions can be drawn about nutritional interventions.

AUTHOR CONTRIBUTIONS

YY and SZ performed literature search and data collection. XZ and YX performed the risk of bias assessment. YY, SZ, and JC conducted the study design and wrote the manuscript. XY provided scientific proofreading and supervised the study.

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BRIEF RESEARCH REPORT
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Tracking the Influence of Predictive Cues on the Evaluation of Food Images: Volatility Enables Nudging

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In previous research on the evaluation of food images, we found that appetitive food images were rated higher following a positive prediction than following a negative prediction, and vice versa for aversive food images. The findings suggested an active confirmation bias. Here, we examine whether this influence from prediction depends on the evaluative polarization of the food images. Specifically, we divided the set of food images into "strong" and "mild" images by how polarized (i.e., extreme) their average ratings were across all conditions. With respect to the influence from prediction, we raise two alternative hypotheses. According to a predictive dissonance hypothesis, the larger the discrepancy between prediction and outcome, the stronger the active inference toward accommodating the outcome with the prediction; thus, the confirmation bias should obtain particularly with strong images. Conversely, according to a nudging-in-volatility hypothesis, the active confirmation bias operates only on images within a dynamic range, where the values of images are volatile, and not on the evaluation of images that are too obviously appetitive or aversive; accordingly, the effects from prediction should occur predominately with mild images. Across the data from two experiments, we found that the evaluation of mild images tended to exhibit the confirmation bias, with ratings that followed the direction given by the prediction. For strong images, there was no confirmation bias. Our findings corroborate the nudging-in-volatility hypothesis, suggesting that predictive cues may be able to tip the balance of evaluation particularly for food images that do not have a strongly polarized value.

Keywords: predictive dissonance, nudging, volatility, evaluative processing, naturalistic food images

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INTRODUCTION

In the last decade, theoretical accounts of brain and mind have pulled predictive processing to the foreground as a core aspect in many, if not all, of the functions traditionally studied in psychology, including perception, memory, attention, learning, and decision making. Bayesian inference, active inference, and discussions of prediction error minimization prove to be powerful tools, not only in modeling human behavior, but also in understanding the underlying neural mechanisms (Friston et al., 2013; Fitzgerald et al., 2015; Hohwy, 2017; Rigoli et al., 2017; Wagenmakers et al., 2018a,b). This theoretical approach with a dominant role for prediction derives principally from earlier,

empirical work on the neural correlates of reward and decision making (reviewed in Schultz, 2015; see also D'Astolfo and Rief, 2017; O'Doherty et al., 2017). The archetypal finding, although not entirely unchallenged, is that the activity of dopamine neurons corresponds to reward prediction error. A positive prediction error, say, an unexpected reward, is associated with an increase in dopamine activity, whereas a negative prediction error is associated with a decrease in dopamine activity. However, a positive prediction error may not necessarily be associated with a positive affect, given the dissociation between "wanting versus liking" and the complexity of pleasure systems in the brain (Berridge and Kringelbach, 2015).

Similarly, it is unclear whether or how the prediction errors may influence concurrent evaluative processing. Take a value-based judgment task with tricks or treats. How would a predictive cue influence the subsequent evaluation, particularly if the outcome does not match with the prediction? Will we give a higher evaluation to a surprise treat, or to an expected treat? Considering the concept of dopamine prediction error and its complex connection to affect, it is not immediately clear how the influence of the prior should play out. On the one hand, one might point out that the predictive cue should generate an initial dopamine prediction error, activating a positive or negative anticipation that could bias the subsequent evaluation. On the other hand, in case of a violation of the prediction, the trick or treat should itself generate a second dopamine prediction error, which could override the first signal and affect the evaluation of the presented item. Would we see bias in line with the prediction (higher ratings for expected treats) or an opposite effect (higher ratings for surprise treats)? In our previous study, we asked this question empirically, using an evaluation task with a bivalent set of food images (Ounjai et al., 2018). Our data showed that appetitive food images were rated higher following a positive prediction than following a negative prediction, and vice versa for aversive food images. Thus, the evaluations tended to be biased in the direction of the prediction.

In our previous study (Ounjai et al., 2018), analysis of the reaction times further showed that valid predictions (e.g., a positive prediction followed by an appetitive food image) produced faster evaluations than invalid predictions. Moreover, during the waiting period between the predictive cue and the target image, we observed gaze biases indicative of a preparatory process in line with the prediction. For instance, with a continuous rating scale from −10 on the left to +10 on the right, the subject's gaze tended to be biased to the right half of the screen following a positive cue, even before the appearance of the food image. Such gaze biases suggested that the influence from the predictive cue depended on active, voluntary processing. The entire pattern of data was interpreted as an active confirmation bias, by which subjects effectively used the predictive cues to guide their subsequent evaluative processing toward confirming what is expected. This finding added to a growing set of studies tracking self-reinforcing expectancy effects (Jepma et al., 2018) and the integration of context into evaluation (Schmidt et al., 2017).

Here, we take a closer look at this type of confirmation bias by considering the level of discrepancy between prediction and outcome. For instance, following a negative cue, the presentation of a strongly appetitive image would reflect a larger expectation violation than the presentation of a moderately appetitive image. We use the term "polarization" to indicate the extent to which the ratings tend toward the polar extremes–either extremely positive or extremely negative–the more extreme, the more polarized (see, e.g., Askarisichani et al., 2019, for a similar usage of the term "polarization").

Importantly, the literature on expectation violations appears to imply conflicting views on how the size of the violation might affect subsequent evaluative processing. According to a theory of predictive dissonance (Kaaronen, 2018), the processing following expectation violations can be compared with the active efforts toward the reduction of cognitive dissonance (Festinger, 1957). Stronger efforts would be required with greater magnitude of dissonance. One approach to dissonance reduction is by selectively harvesting sensory information, which is consonant with our predictions–the "dark side" of this would be confirmation bias (Clark, 2016). Applying these ideas to the current context, we derive a predictive dissonance hypothesis by which the confirmation bias–or the tendency to stick with the prediction despite the outcome–should be most active with highly polarized food images, leading to strong influences from the predictive cue.

Alternatively, several studies have emphasized that volatility is a critical factor in value updating (Massi et al., 2018; Findling et al., 2019). Volatility, here, would pertain to the affective values of various stimuli. Strongly appetitive or strongly aversive images should have less volatile affective values, consistently eliciting very polarized evaluations. Instead, moderately appetitive or aversive stimuli may generate more imprecision in subjects' evaluations, sometimes liked or disliked, more susceptible to subjective differences. The predictive cues would then be more influential for stimuli with volatile affective values (i.e., moderately appetitive or aversive) than for stimuli with stable affective values (i.e., strongly appetitive or aversive). Thus, the predictions might tip–or nudge–the balance one way or another only within a dynamic range for food images whose value is less salient. Analogous to the concept of nudging in behavioral economics (Thaler and Sunstein, 2008; see also Noggle, 2018), we label this hypothesis as "nudging in volatility."

Concretely, reanalyzing our previous data (Ounjai et al., 2018), we investigate in the present study how the confirmation bias operates with strong versus mild images. According to the predictive dissonance hypothesis, the confirmation bias should be more pronounced for strongly polarized food images than for less polarized food images. Thus, for strong positive images, the ratings should be higher after positive cues than after negative cues; for strong negative images, the ratings should be lower after negative cues than after positive cues. These cue validity effects would be less pronounced with mild images.

According the nudging-in-volatility hypothesis, for mild positive images, the ratings should be higher after positive cues than after negative cues; for mild negative images, the ratings should be lower after negative cues than after positive cues. These cue validity effects would be less pronounced with strong images.

METHODS

The current study is based on a reanalysis of the data set that was published previously by Ounjai et al. (2018). For present purposes, we considered only the manual joystick responses with the evaluative ratings, particularly in trials with positive or negative predictive cues that could produce expectation violations.

Subjects

In Experiment 1, there were 42 subjects. All were Kyushu University students (26 male and 16 female subjects) with a mean age of 22.45 ± 3.63 years. In Experiment 2, there were 66 subjects. All were Kyushu University students (38 male and 28 female subjects) with a mean age of 23.94 ± 4.54 years. In both experiments, all subjects had normal or corrected-to-normal vision. All subjects gave informed consent and reported that they were in healthy condition before and after the experiment.

Apparatus and Stimuli

The visual stimuli were presented in a dimly lit room on a 23.8-inch full-high-definition flat-panel monitor, with a display resolution of 1,920 × 1,080 pixels. The subjects were seated approximately 62 cm from the monitor. To minimize head movement, a chin rest with a forehead support was used. The evaluation responses were recorded using a joystick (Logitech, Switzerland; model no. 963290-0403). All visual stimuli were presented as inset images on a white background in the middle of the otherwise black screen. The size of the inset image was fixed at 380 × 380 pixels for the predictive cues, and at 600 × 600 pixels for the food images. The predictive cues were icons: a tray for positive and a hazard sign for negative. We also used a checkerboard for neutral cue. Food images were drawn from the FoodCast research image database (FRIDa), developed by Foroni et al. (2013). This database was supplemented with non-copyrighted images to construct a set of 200 food images with a balanced range of appetitive and aversive stimuli.

Experimental Procedures

Experiment 1

Participants were asked to evaluate 180 naturalistic food images in three consecutive blocks of 60 trials. At the start of each trial, the word "short" or "long" was presented for 1 s in the middle of the screen to indicate the delay time between the predictive cue and the target image, either 1 or 9 s. Next the predictive cue was shown at the center of the screen for 1 s, followed by the blank screen for the delay period. Then, the target image was shown for 2 s and in turn replaced by the response screen. The subject had maximally 6 s to evaluate the food image by bending the joystick to move the cursor on the evaluation bar from −10 to 10. The bending angle was used to indicate the evaluation score. After the response was made, there was a blank screen for 2 s as intertrial interval.

Different icons were used for the predictive cues to indicate the outcome, either appetitive or aversive, whereas the color indicated the reliability level of the cue, either 100% certain or 50% uncertain. Here, 50% positive predictive cues refer to food-tray cues, whereas 50% negative cues refer to danger-sign cues. Rationally speaking, these predictive cues were uninformative; however, we reasoned that learned associations might elicit "framing effects" (i.e., cognitive biases). Accordingly, this also raises an important limitation of the present (and our previous) study. These predictive cues were not visually neutral.

The color assignment was counterbalanced across subjects. The reliability of the predictive cue was further indicated numerically in percentage, presented in small print beneath the icon.

The evaluations had to be given on a continuous rating scale from −10 to 10, with a value of −10 for a maximally disgusting food image and a value of +10 for a maximally attractive food image.

The experiment included 180 trials, consisting of 15 repetitions of each of the 12 conditions, with three levels of cue type (certain, valid, invalid), two levels of outcome type (positive and negative), and two levels of delay time (1 s and 9 s). No food image was presented more than once. The 180 trials were presented in pseudorandom order to ensure that each block of 60 trials contained five repetitions of each condition.

For present purposes, for Experiment 1, we analyzed only the trials with potential expectation violations; thus, we analyzed only the trials with 50% positive or negative predictive cues. Additionally, because there were no effects of delay, we pooled the data of the 1-s and 9-s delay trials.

Experiment 2

Participants were asked to evaluate 200 naturalistic food images in four consecutive blocks of 50 trials. The procedures were the same as in Experiment 1 except for the following. The delay time between the predictive cue and the food image was fixed at 2 s, and no word cue was given to indicate the delay time at the beginning of the trial. The cue reliability for the positive and negative cues was fixed at 75%, and a third type of cue was included (a neutral cue, represented by a checkerboard as icon).

The evaluation bar assignment was changed for two groups of subjects, with either a conventional alignment (negative–left, positive–right) or the opposite alignment. Here, subjects were asked to confirm their evaluation by clicking the trigger on the joystick.

The experiment included 200 trials, divided into six conditions, with three levels of cue type (valid 75%, neutral, invalid 25%) and two levels of outcome type (positive and negative). The valid 75% conditions consisted of 60 repetitions, whereas the invalid 25% and the neutral conditions each consisted of 20 repetitions. No food image was presented more than once. The 200 trials were presented in pseudorandom order to ensure that each block of 50 trials contained the same distribution of trials per condition.

For present purposes, for Experiment 2, we analyzed only the trials with positive or negative predictive cues; thus, we analyzed only the valid 75% and invalid 25% conditions.

Analysis

The dependent measure of interest in the current study was the evaluative ratings on a scale from −10 to +10. In order

to facilitate the comparison across appetitive and aversive images, we flipped the sign of the evaluations so that all ratings (most appetitive as well as most aversive) tended toward +10. In order to examine the effects of the predictive cues as a function of the intrinsic polarization of the images, we separated "strong" from "mild" images via a median split based on the overall average ratings of the food images collapsed across all conditions and all subjects (i.e., based on the data in Figure 1 of Ounjai et al., 2018). Then, separately for each experiment, we performed a three-way within-subjects repeated-measures analysis of variance (ANOVA) on the average ratings of the food images. In this analysis, the three within-subjects factors were valence (appetitive or aversive images), polarization (strong or mild images), and validity (valid prediction or invalid prediction). To address the present research question directly, separately for each experiment, we performed planned contrasts, using paired *t*-tests, pooled across appetitive and aversive images. For each subject, we calculated the validity effects (valid minus invalid) separately for strong images and for mild images.

Finally, to assess the overall strength of the evidence for or against the predictive dissonance hypothesis and the nudging-in-volatility hypothesis, we conducted Bayesian testing as follows. Pooled across both experiments and pooled across appetitive and aversive images, we computed for each subject the validity effects (valid minus invalid) for strong images and for mild images. Then, we performed Bayesian paired *t*-testing on the validity effect measures for strong versus mild images, with subjects as degrees of freedom. This was done with two different alternative hypotheses: in the first test, the null hypothesis was pitched against the predictive dissonance hypothesis (implying that strong images should yield larger validity effect measures than mild images); in the second test, the null hypothesis was pitched against the nudging-in-volatility hypothesis (implying that strong images should yield smaller validity effect measures than mild images). The Bayesian testing was conducted following the guidelines and using the JASP software package provided by Wagenmakers et al. (2018a,b).

RESULTS

The mean ratings for Experiment 1 are presented in **Figure 1** as a function of the valence of the images (appetitive or aversive), the polarization (strong versus mild), and the validity of the cue–target relationship (valid or invalid). The three-way ANOVA produced significant main effects of the valence of the images, $F(1,41) = 5.279$, Mean Squared Error (MSE) = 8.474, $\eta_p^2 = 0.114$, $p < 0.05$, and the polarization of the images, $F(1,41) = 149.696$, MSE = 1.362, $\eta_p^2 = 0.785$, $p < 0.001$. The main effect of the validity of the cue–target relationship was not significant, $F(1,41) = 2.867$, MSE = 1.346, $\eta_p^2 = 0.065$, $p = 0.098$. The interaction between validity and polarization was significant, $F(1,41) = 6.963$, MSE = 0.626, $\eta_p^2 = 0.145$, $p < 0.05$. The other interactions were not significant: valence by cueing [$F(1,41) = 0.432$, MSE = 0.441, $\eta_p^2 = 0.010$, $p = 0.515$], polarization by cueing [$F(1,41) = 1.668$, MSE = 0.769, $\eta_p^2 = 0.039$, $p = 0.204$], or the three-way interaction [$F(1,41) = 0.001$, MSE = 0.589, $\eta_p^2 = 0.001$, $p = 0.979$].

To address our present research question directly, we conducted planned contrasts for the validity effects separately for strong images and mild images. For strong images, valid cues yielded a ratings average of 7.111 (SD = 1.325), whereas invalid cues yielded a ratings average of 7.020 (SD = 1.435); this validity effect was not significant, $t(41) = 0.816$, $p = 0.419$, Cohen $d = 0.126$. For mild images, valid cues yielded a ratings average of 5.677 (SD = 1.447), whereas invalid cues yielded a ratings average of 5.339 (SD = 1.356); this validity effect was not significant, $t(41) = 1.734$, $p = 0.091$, Cohen $d = 0.267$.

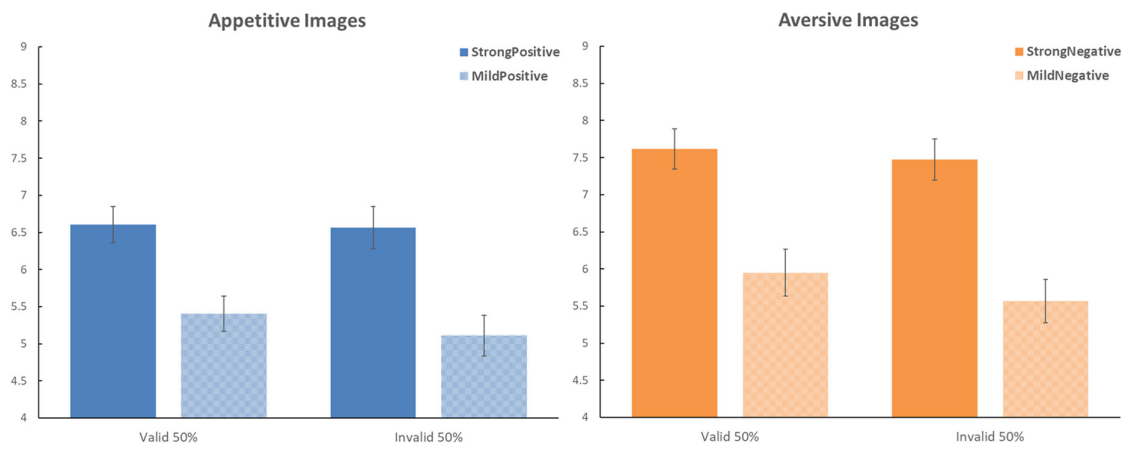

FIGURE 1 | Effects of predictive cues on the evaluation of food images in Experiment 1. The **left panel** shows the data for the appetitive images. The **right panel** shows the data for the aversive images. Dark blue and dark orange bars present the data for the strong images; the light-shaded bars present the data for the mild images. On the horizontal axes, the bars are separated as a function of the validity of the predictive cues. Error bars represent the standard error of the mean. In this experiment, the framing by the predictive cues did not correlate with the outcome; there was an equal probability for the cue to be valid (i.e., matching valence with the outcome) or invalid (i.e., mismatching valence with the outcome).

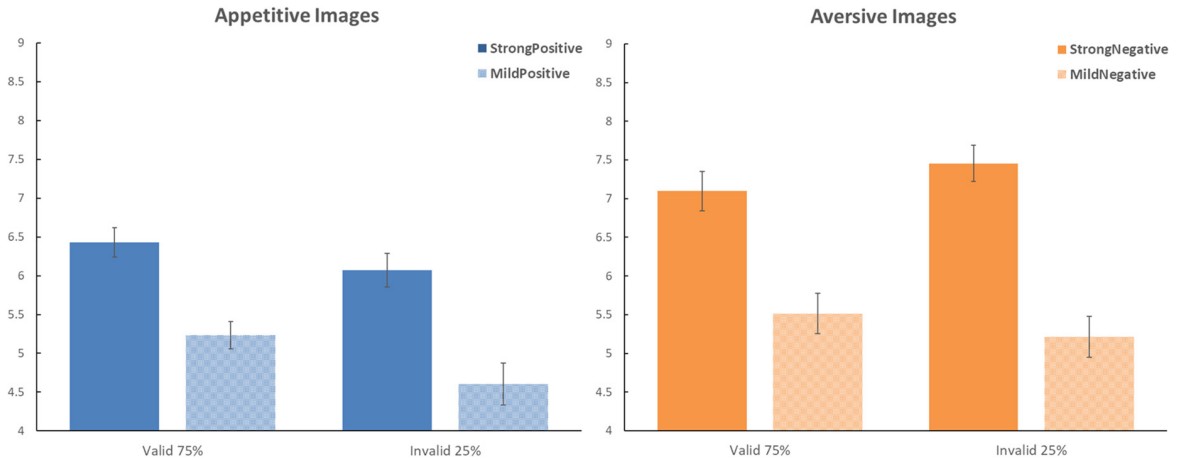

FIGURE 2 | Effects of predictive cues on the evaluation of food images in Experiment 2. Same format as in **Figure 1**. In this experiment, the framing by the predictive cues correlated with the outcome; there was a 75% probability for the cue to be valid (i.e., matching valence with the outcome) versus 25% probability for the cue to be invalid (i.e., mismatching valence with the outcome).

The mean ratings for Experiment 2 are presented in **Figure 2** in the same format as in **Figure 1**. The three-way ANOVA produced significant main effects of the valence of the images, $F(1,65) = 8.358$, MSE = 8.553, $\eta_p^2 = 0.114$, $p < 0.01$, and the polarization of the images, $F(1,65) = 281{,}662$, MSE = 1.231, $\eta_p^2 = 0.812$, $p < 0.001$. The main effect of the validity of the cue–target relationship was not significant, $F(1,65) = 3.092$, MSE = 2.317, $\eta_p^2 = 0.045$, $p = 0.083$. There were significant interactions between validity and polarization, $F(1,65) = 12.566$, MSE = 0.557, $\eta_p^2 = 0.162$, $p < 0.001$; between validity and valence, $F(1,65) = 9.654$, MSE = 0.949, $\eta_p^2 = 0.129$, $p < 0.005$; and between polarization and valence, $F(1,65) = 14.068$, MSE = 0.793, $\eta_p^2 = 0.178$, $p < 0.001$. The F value for the three-way interaction was not significant, $F(1,65) = 2.270$, MSE = 0.562, $\eta_p^2 = 0.034$, $p = 0.137$.

Again, as in Experiment 1, we conducted planned contrasts in Experiment 2 to examine the validity effects separately for strong images and mild images. For strong images, valid cues yielded a ratings average of 6.764 (SD = 1.541), whereas invalid cues yielded a ratings average of 6.762 (SD = 1.442); this validity effect was not significant, $t(65) = 0.021$, $p = 0.983$, Cohen's $d = 0.002$. For mild images, valid cues yielded a ratings average of 5.374 (SD = 1.441), whereas invalid cues yielded a ratings average of 4.911 (SD = 1.628); this validity effect was significant, $t(65) = 2.764$, $p < 0.01$, Cohen $d = 0.340$. Thus, in Experiment 2, there was a significant confirmation bias only for mild images.

Finally, Bayesian testing provided overall estimates of the strengths of the evidence for or against the present hypotheses under investigation, based on the data pooled across both experiments. The descriptive statistics for the sample of 108 subjects showed a mean of 0.037 (SD 0.906) for the validity effect measures with strong images versus a mean of 0.415 (SD 1.320) for the validity effect measures with mild images.

Figure 3 shows the inferential plots of a Bayesian paired t-test with predictive dissonance as the alternative hypothesis, implying greater validity effect measures for strong than for mild images. With a Bayes factor BF_{0+} of 41.08, the evidence was very strong in favor of the null hypothesis over the predictive dissonance hypothesis. Conversely, **Figure 4** shows the inferential plots of a Bayesian paired t-test with nudging in volatility as the alternative hypothesis, implying smaller validity effect measures for strong than for mild images. The Bayes factor BF_{-0} of 56.29 indicated that the evidence was very strong in favor of the nudging-in-volatility hypothesis rather than the null hypothesis.

DISCUSSION

Bivalent predictive cues produce an active confirmation bias in a value-based judgment task with naturalistic food images (Ounjai et al., 2018). Here, we investigated the operation of the confirmation bias as a function of the size of the expectation violation. Specifically, we reanalyzed our data set through an item analysis that separated "mild" from "strong" food images, based on their overall ratings across all conditions. Mild images, in case of a mismatch with the valence of the predictive cue, represent a smaller expectation violation than strong images. This moderate versus extreme polarization in the values of the images turned out to modulate the active confirmation bias significantly in the present data. For mild images, we obtained solid cue validity effects, indicating the operation of a confirmation bias, with more positive ratings for appetitive images following a positive predictive cue than following a negative predictive cue, and vice versa. For strong images, we did not obtain significant cue validity effects.

Our findings support the nudging-in-volatility hypothesis, suggesting that the predictive cues are influential predominately for food images that do not have a strongly polarized value. In line with previous findings on the critical aspect of volatility (Massi et al., 2018; Findling et al., 2019), we propose that the mild images have relatively unstable value associations that make them

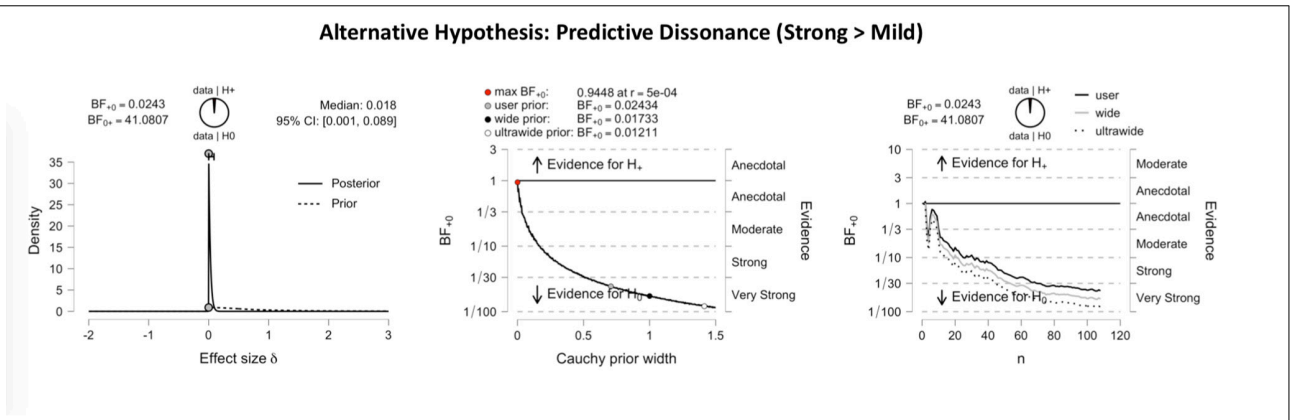

FIGURE 3 | Inferential plots of Bayesian paired-samples *t*-test, with predictive dissonance as the alternative hypothesis. The **left panel** shows the posterior and prior; the **middle panel** shows the Bayes factor robustness check, and the **right panel** shows the sequential analysis. With a Bayes factor BF_{0+} of 41.08, the evidence appears very strong in favor of the null hypothesis as compared to the predictive dissonance hypothesis.

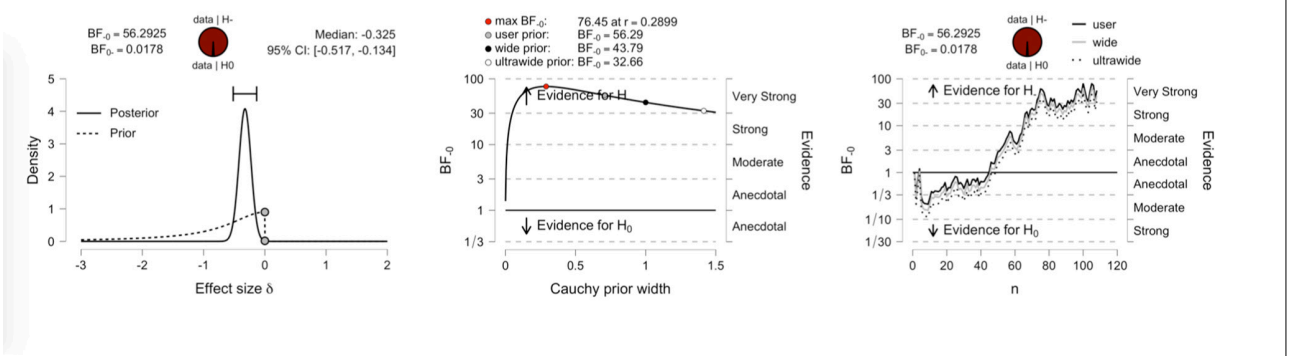

FIGURE 4 | Inferential plots of Bayesian paired-samples *t*-test, with nudging in volatility as the alternative hypothesis. Same format as in **Figure 3**. With a Bayes factor BF_{-0} of 56.29, the evidence appears very strong in favor of the nudging-in-volatility hypothesis as compared to the null hypothesis.

susceptible to the prodding or nudging by predictive cues. Thus, the volatility enables nudging.

Within the framework of active inference, our findings are consistent with the notion that top-down bias is most evident under increased sensory uncertainty (Hohwy, 2017). More specifically, when a stimulus with a volatile affective value follows an unambiguous predictive cue, this would elicit a precision prediction error. The predictive cue itself was categorical: either positive or negative. Yet, a food image with volatile value would be harder to classify. The resulting prediction error then would be imprecise. In terms of active inference and updating, Friston et al. (2016) have discussed in detail how such a precision prediction error, signaled by dopamine, effectively drives down the gain on the prediction error. In other words, less updating will follow from the prediction error because imprecise prediction errors cannot be trusted. The inference is then weighted more by the prior, induced by the predictive cue. The prediction becomes more influential. Hence, in the present paradigm, the confirmation bias occurs particularly under this imprecision, with target images that have volatile affective values.

Subjects might–consciously or unconsciously–turn to the external information, provided by the predictive cue, particularly when they are in doubt about the value of a given food image. Interestingly, this notion of extra information integration under doubt is also compatible with other findings from our laboratory on the cognitive mechanisms underlying the evaluation of food images. Particularly, across two connected studies, Wolf et al. (2018, 2019) found that subjects tended to gaze longer at images for which they felt uncertain about the evaluation, completely against the prevailing notion in the literature that "viewing leads to liking." Again, the finding of longer gazing at items that are not clearly liked or disliked can be interpreted in terms of volatility. That is to say, volatility appears to be a condition that is more likely to lead to value updating or information integration toward improving the prediction precision.

The present data offer firm evidence against the predictive dissonance hypothesis–at least our current derivation in the present experimental paradigm. To be sure, this in no way discredits the theory of predictive dissonance (Kaaronen, 2018).

Rather, we suggest that our present findings introduce a critical dimension to be considered in the theory of predictive dissonance. One way of interpreting the current data would be to flip the perspective and emphasize that strong images, with stable value associations, are impervious to outside influence. Against these strong images, the predictive cues have limited power, likely because the subjects have no particular affective investment in them. The prediction, or "the belief," implied by the cue has little or no meaning to the subjects in the larger scheme of things. This is very different from other kinds of beliefs and predictions that may be of deep personal importance to individuals (e.g., "Climate change is a hoax"). There may indeed be strong resistance against accepting evidence that challenges a person's core views, particularly when the evidence is striking and would require a fundamental revision. Thus, we propose that, in the theory of predictive resonance, a critical weight factor in the prediction should be included. Without much weight to the prediction, nudging may work for volatile values, while the predictive information provided by the cues is largely abandoned for images with strongly polarized, stable values.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Ethics Committee of the Faculty of Arts and Science, Kyushu University (Issue number 201711). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KO, JH, and JL contributed to the design of the study. KO conducted the data collection for the study, analyzed the data with LS, and prepared the figures. JL wrote the manuscript. All authors reviewed and approved the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.569078/full#supplementary-material

DATA SHEET S1 | Complete data set for the present study, organized in three Data Sheets: Experiment 1, Experiment 2, and Pooled for Bayesian.

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Recognizing Decision-Making Using Eye Movement: A Case Study With Children

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The use of visual attention for evaluating consumer behavior has become a relevant field in recent years, allowing researchers to understand the decision-making processes beyond classical self-reports. In our research, we focused on using eye-tracking as a method to understand consumer preferences in children. Twenty-eight subjects with ages between 7 and 12 years participated in the experiment. Participants were involved in two consecutive phases. The initial phase consisted of the visualization of a set of stimuli for decision-making in an eight-position layout called Alternative Forced-choice. Then the subjects were asked to freely analyze the set of stimuli, they needed to choose the best in terms of preference. The sample was randomly divided into two groups balanced by gender. One group visualized a set of icons and the other a set of toys. The final phase was an independent assessment of each stimulus viewed in the initial phase in terms of liking/disliking using a 7-point Likert scale. Sixty-four stimuli were designed for each of the groups. The visual attention was measured using a non-obstructive eye-tracking device. The results revealed two novel insights. Firstly, the time of fixation during the last four visits to each stimulus before the decision-making instant allows us to recognize the icon or toy chosen from the eight alternatives with a 71.2 and 67.2% of accuracy, respectively. The result supports the use of visual attention measurements as an implicit tool to analyze decision-making and preferences in children. Secondly, eye movement and the choice of liking/disliking choice are influenced by stimuli design dimensions. The icon observation results revealed how gender samples have different fixation and different visit times which depend on stimuli design dimension. The toy observations results revealed how the materials determinate the largest amount fixations, also, the visit times were differentiated by gender. This research presents a relevant empirical data to understand the decision-making phenomenon by analyzing eye movement behavior. The presented method can be applied to recognize the choice likelihood between several alternatives. Finally, children's opinions represent an extra difficulty judgment to be determined, and the eye-tracking technique seen as an implicit measure to tackle it.

Keywords: eye movements, recognizing, decision-making, children, product

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INTRODUCTION

The novel collaboration between consumer, scientist, and marketing experts leads to better identification, recognition, and understanding of consumer behavior. Self-report and behavioral measurements are the instruments that have been used to study the consumer's experience, thoughts, and emotions. In the last decade, the use of self-report surveys and visual representation tools has demonstrated how people can describe their reactions and decision-making process in choosing products and services (Poels and Dewitte, 2006). Advances in neurosciences, neurobiology, and neuropsychology increase our knowledge of how brain works (Crone and Ridderinkhof, 2011; Blanco et al., 2014), and how reality is interpreted through daily-life experiences, the interaction with the environment, and daily decision-making (Lăzăroiu, 2017).

The contributions generated by applying concepts of neuroscience to consumer research have been significant due to the application of physiological measures in the last years (Hubert and Kenning, 2008; Wang and Minor, 2008; Solnais et al., 2013; Hubert, 2010). Karmarkar and Plassmann (2017) discuss extensively the integration of neurophysiological data in consumer research, mainly describing the ability of consumer behavior prediction and decision-making, breaking boundaries established by conventional techniques. Neuroscience techniques offer the ability to recognize implicit measurements not controlled by conscious processes (Lieberman, 2007), revealing cognitive process that can be approached from the modifications of sensory stimuli to people's attention elements (Ochsner and Gross, 2005). Advances in the application of implicit measurements have led to a wide range of physiological measurement techniques to be now considered as tools for consumer recognition. These tools are considered a step ahead in self-report in consumer research (Bell et al., 2018), which should be reviewed for deeper application. Some of the most used tools for physiological measurement are electroencephalogram (EEG), functional MRI (fMRI), electrodermal activity (EDA), heart rate (HR), and eye movement (also, eye-tracking; Wedel and Pieters, 2006; Smidts et al., 2014; Hsu and Yoon, 2015; Hsu, 2017; Karmarkar and Plassmann, 2017; Bell et al., 2018).

Eye movement or gaze attention is a widely used tool to assess people's behavior, including children, in order to know which visual stimuli are liked and chosen. Mitsura and Glaholt (2014) demonstrated how gaze behaves more strongly in a liking decision than dislike decision, and also the young participants in the study were not greatly influenced by the categorization of the stimuli. The relationship between eye-movements and preference has been studied repeatedly, but research with samples of children is limited. Old studies of eye movement have demonstrated its application to identify preferences, even in children. They show that if a stimulus is observed more times, that is the preferred one (Fantz, 1963, 1964). Measuring gaze and how it affects decision-making provides important information on the nature of stimuli, and attention level can stimulate the consumer preference (Djamasbi, et al., 2010; Rojas et al., 2015; Van der Laan et al., 2015; Yaramothu et al., 2018; Qu and Gou, 2019; Steinhauser et al., 2019). Shimojo et al. (2003) and Simion and Shimojo (2006, 2007) explained the first indicator of a gaze bias that exists during selection between two visually present stimuli. The experimentation with two elements presented and selected on attractiveness showed that eye movement is biased toward the element that was later selected. This gaze bias becomes evident between 1 and 1.5 s prior to the response that marked the overt decision. Other studies have shown that the observed stimulus is an important factor for generating an attentive gaze (Park et al., 2010; Liao et al., 2011). One of these studies replicates a two-alternative preference judgment task between a new stimulus and a repeatedly know stimulus. The results indicated that a facial stimulus is more familiar than any other type of stimulus. Recently, Morii and Sakagami (2015) showed how the gaze cascade effect phenomenon is an indicator of preferred judgment, where the choice of a stimulus is within the viewing time. However, the selection between two alternatives often does not correspond to the reality of decision-making between stimuli. Glaholt et al. (2009) demonstrated that the bias in looking behavior was particularly robust in eight-alternative forced-choice (8-AFC) decision tasks. These findings imply that, by monitoring eye movements, it may be possible to recognize the observers' selection or preference prior to the overt response and possibly prior to the point at which the selection is consciously made. In another experiment, Glaholt and Reingold (2012) replicated the effect of modulating visual attention and decision-making of a stimulus observed in an arrangement of several images, obtaining similar results.

The potential of the eye movement method can reveal information about children's gaze behavior. In contrast, according to the literature related to self-reports, children can be assessed through different traditional methods, but there are multiple limitations such as age-group of interest, styling of self-report instruments, response formats for self-report, language, space contamination, concrete or styling stimuli, and design elements to consider (Song et al., 1994; Chambers, 2002; Sturgess et al., 2002; Kuijpers et al., 2014). This limitation types gives partial information when we use self-report, however, possibilities using the implicit measure combined the traditional assessment and gaze or eye movement can support a novel consumer research. In the same line of thought, the gaze can provide a predictive application for choice alternatives. Previous findings have shown the contribution to consumer behavior understanding through an implicit measure, and implication in decision-making process through the gaze. In order to measure the children's attention in Saegusa et al. (2015) experiment, stimuli were designed such these could be attractive and familiar to the sample. In similar experiments, there is a justification for understanding the attractiveness of certain stimuli to people.

Another reasoning for the choice of recognizable or familiar stimuli is the heuristic recognition theory and the research on the processing of decision-making according to a few researches of the last years. Marewski et al. (2009) suggest that simple cognitive mechanisms may outperform complex cognitive processes that are mostly noise in people's minds. Simple judgments should not require complex understanding. Furthermore, Arkes et al. (2016) argue that consistency is a

basic rule to understand behavior. So too, coherence plays a key role in situations where it is instrumental in achieving functional goals. In the last decade, Gigerenzer and Goldstein (2011) have described how judgment and decision-making can be described as a simple heuristic model. Also, Pachur et al. (2011) opened the debate on the processes underlying the use of recognition in decision-making. The authors suggest that recognition is often an ecologically valid signal, that people often follow recognition when making inferences. In terms of human behavior, recognition seems to have a special status in decision-making.

For this research, we include elements that are familiar and that will be easily recognized by the participants. For example, faces are a stimulus that has a level of attractiveness or beauty that is often associated with desire. In addition, faces are associated with emotional aspects (Saegusa et al., 2015) and the familiarity that these can represent to a person to leads to preference (Liao et al., 2013) and recognize the capacity of remind aspect related to consumer experience (Heljakka and Ihamäki, 2019). The stimulus, due to its familiarity, can change a consumer's decision-making process. The visual attention that a familiar stimulus can represent can be full of emotional components and attractive physical attributes. There is an enormous relationship between good physical attributes with good emotional components in product configuration (Hertenstein et al., 2013), and the attractiveness generated by this (Joško-Brakus et al., 2014; Kareklas et al., 2014), transmitted through different visual media (physical or digital), can affect decision-making or preference (Cowart et al., 2008; Cho and Kim, 2012).

Tanaka et al. (2001) distinguished three basic attributes to perceive objects: shape, color, and texture. These three attributes give a complete "object representation" leading to more complex cognitive processes, giving us the ability to understand the visual elements. Through form, texture, objects, color, and intensities, a familiar stimulus to children could stand out and serve as an attraction to attractor the consumer's attention (Kwon et al., 2002; Luo, 2006; Lin, 2010; Festila and Chrysochou, 2018). Specifically, color plays a fundamental role as a factor of aesthetic attractiveness to everybody, from a perceptual aspect (Helo et al., 2014) to the emotional aspect (Green-Armytage, 2006). Various studies have demonstrated the importance and influence of such attributes (related with brands) on the perceived quality of a product (Grunert et al., 2004; Laforet, 2011). In our case configuration, the stimuli are provided by toys to manage and facilitate their visualization by and familiarization with children, just as in the examples described by Hult et al. (2019) for consumer experience.

The aim of this paper is to examine, through stimuli designed with elements familiar to children, attractive attributes and emotional components, the decision-making recognition when showing different stimuli alternatives in 8-AFC decision tasks and traditional assessment of the stimuli. The implementation of an implicit measure will support the limitation, difficulty, and even the ethical implications of using children as a sample for this research or any type of sample in similar studies (Stanton et al., 2017). The information that this investigation will give us using the behavior of gaze as an implicit measure can contribute to the comparison of physiological measures and self-reports.

MATERIALS AND METHODS

Participants

This study was conducted with 30 children aged 7–12 years, divided in two groups for the two groups of stimuli. Twenty-eight children (14 girls, M = 9.5 years; SD = 1.7) took part in the experiment. The parents' permission was requested to conduct the experiments. All methods and experimental protocols were performed in accordance with the guidelines and regulations of the local ethics committee of the Polytechnic University of Valencia.

Instrumentation

An unobtrusive eye tracker capable of recording the position of the eyes at a sampling rate of 300 Hz (Tobii TX300, Tobii, Stockholm, Sweden) was used to measure the participants' visual fixations. This device has a 23″ flat HD screen and a sensor bar in the lower part of it. This setup allows participants to make large head movements, and to move freely and naturally in front of the screen. Tobii Studio 3.2.1 software was used to calibrate the eye tracker, to present the stimuli and record the data.

Stimuli

For the experiment, two groups of stimuli were created following a simple design base. Icons and toys were designed and constructed with a unique combination of three stimulus dimensions. The first group (icon) used as dimensions: a character (animal), a color, and a detail eye. For each dimension, five options were selected to create 125-possible combination of icons. The second group (toys) was designed follow the same construction, three dimensions were used: a character (animal), a color, and a material. For each dimension, five options were selected to create 125-possible combination of toys. However, the 125 combinations for each group were not used due to the length of the study, thus it was decided to only take 64 randomly selected combinations from the original set for the experiment. All the possible combinations are shown in **Figure 1**. We verified that the frequency of occurrence the five elements of the icon and toy design had a uniform distribution.

Procedure

The experiment consisted of two tasks that were completed by the participants in a fixed order: 8-AFC and individual visual and verbal evaluation. The sample was randomly divided into two groups balanced by gender. One group of participants was given the icons version of the experiment, and other group was given the toys version. Each participant was given instructions before participating in each component of the experiment. A preparation task was designed to instruct on the 8-AFC task to be performed by the young participants. A complete scheme of the task can be seen in **Figure 2**.

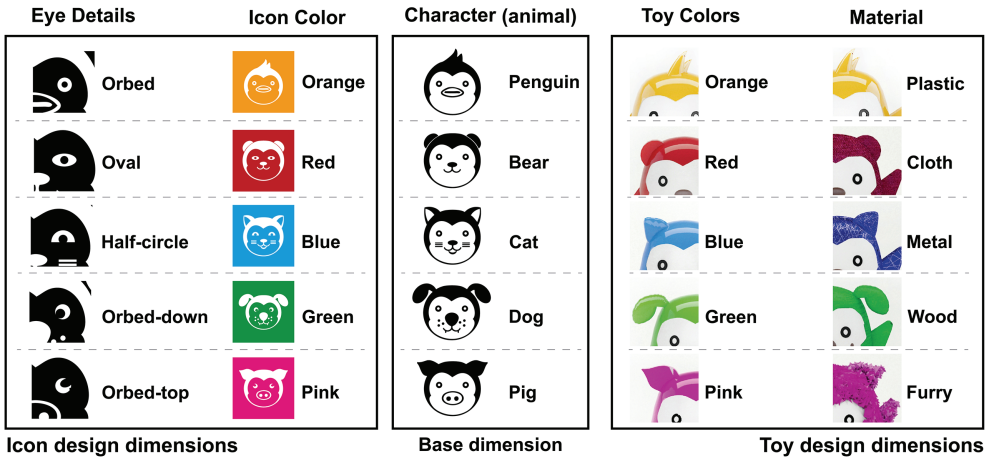

FIGURE 1 | Stimuli dimensions for icons and toys design.

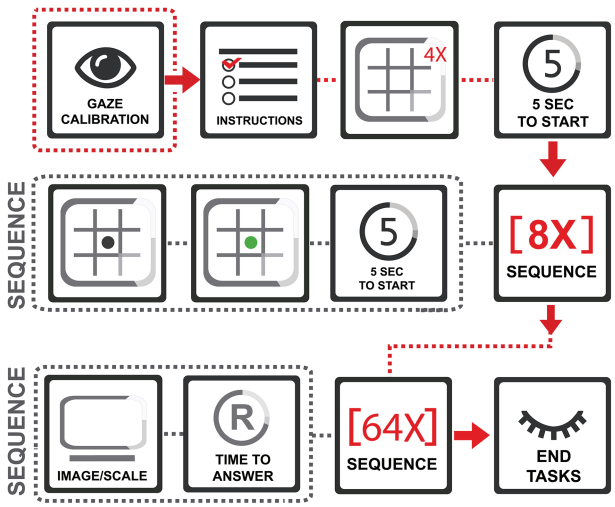

FIGURE 2 | Complete scheme of the task in the experiment.

The first task included the tracking measurement using the method 8-AFC (Glaholt and Reingold, 2009, 2012; Mitsura and Glaholt, 2014) in terms of choice likelihood, in a layout of 3 × 3 boxes, which serves to distribute the eight different options of the 64 icons or toys selected. The stimuli were spread in every box except the central box; inside of this box, a black point is displayed as an indicator to complete task. To begin, the participant had to freely watch the eight different options and choose the favorite one with no limit of time. After that, when the subjects know what stimuli will be chosen, the gaze must move to the black point just for 2 s. Then, the black point turns green color, indicating the beginning of the decision-making part of the task. The participant must return to watch the favorite stimuli to indicate their liking choice using gaze feedback (see **Figure 3**). Eight layouts were designed to cover the 64 combinations of icons and toys. The second task was to perform an independent assessment of each stimuli using a Likert-scale. The same 64 icons and toys from the first task were taken to create a layout for every stimulus. With every stimulus, a Likert-scale (1, I do not like and 7, I like it) was included and the participant made a decision and signaled it by voice with no limit of time (see **Figure 4**).

Data Collection

During the first task, eye-tracking data were obtained using Tobii Studio. It provides the raw data of gaze position in X and Y coordinates according to the stimuli (8-AFC) presented in the screen. A fixation identification algorithm based on the speed of gaze was applied to eye-tracking raw data. The data can be grouped in three classes: (1) if between instants the speed of the gaze was less than a threshold it is considered that a fixation is being made, (2) if it exceeds this speed it is considered as saccade, and (3) and if there has been any error or it is not looking at the screen they are considered non-classified. The identified fixations have been used to model visual attention. Each 8-AFC was segmented in nine areas of interest (AOI) following the 3 × 3 layout: eight AOIs delimited each stimulus (logo or toy) presented, and one delimited the central point used to start the decision-making process. Therefore, each fixation can be assigned to one logo or toy. Using the segmentation, two metrics were computed: total time fixation (TTF), i.e., the summation of the time of all the fixations in one AOI, and visit count (VC), i.e., number of times that the icon or toy was viewed. A visit was defined as the permanency of more than one consecutive fixations in the same AOI, where all of the fixations produce one visit assigned to the AOI. The visit starts when the first fixation starts, and finishes when the last fixation ends, including all the saccades or blinks between the consecutive fixations. Moreover, in order to determine the division between the exploration and the decision-making part of the task, the decision-making instant was defined as the last sample of the last fixation before the visit to the central AOI. All the data processing were perfomed using Matlab R2013.

FIGURE 3 | Stimulus layout from the eight-alternative forced-choice (8-AFC) task for icons version (left) and toys version (right).

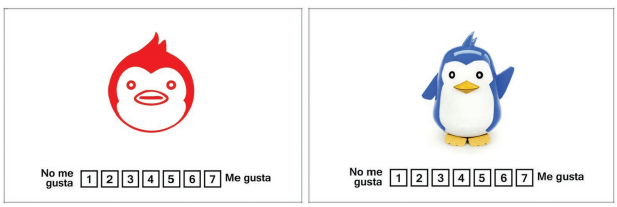

FIGURE 4 | Stimulus layout from the assessment task for icons version (left) and toys version (right).

Statistical Analysis

The self-assessment in terms of preference of the task 2 was computed to analyze the influence of each dimension in the stimuli: color, character, and eyes/materials. After the descriptive statistics analysis of the design dimensions, linear correlations between preference and visual attention have been performed using Pearson correlations. Moreover, the analysis focused on observing the influence that every dimension had on the children's gaze behavior. A Kolmogorov-Smirnov normality test was applied to the data used, which showed that the data followed a normal distribution. The statistical method used for the analysis was a multivariable ANOVA (MANOVA) with a Bonferroni correction. Statistical analysis was performed using SPSS 17.0 for Windows™ (IBM SPSS Inc., Chicago, IL, United States).

In addition, we analyze the recognition level of the liking choice of 8-AFC using the visual attention patterns. To this extent, the total fixation time during two sets of visits were analyzed. In particular, the total fixation time of each stimuli AOI in the first four visits were computed to determine if the most viewed icon or toy in the initial exploration can recognize the choice. Alternatively, the total fixation time of each stimuli AOI in the last four visits before the decision-making instant were computed to determine if the most viewed icon or toy in the moments previous to the decision-making can recognize the choice.

Finally, the evolution of the percentage of TTF that each stimulus achieves during the 8-AFC task was analyzed. To this extent, the eight stimuli were characterized in each trial as the choice, i.e., the stimuli that was chosen, and 1–7 distractors, being 1 the (not chosen) stimuli with highest TTF and 7 the one with lowest TTF. During all the instants of a trial, the percentage of TTF that choice and distractors reach was calculated from the start point until this instant. Since the trials do not have the same duration, all of these the trials were synchronized using the instant of the decision-making. The last 3 s of the all icons and toys trials were averaged separately to characterize the time previous to the decision-making moment.

RESULTS

Self-Assessment Preferences

The results obtained by the assessment of preference during the second task of the experiment are shown in **Figure 5**. The results of the 7-point Likert scale can be used for the assessment of the design dimensions used for icons and toys. The children declared the most liked choices of stimulus which were composed among characteristic, color, material, or eye detail.

Figure 6 shows linear correlation between preference, TTF, and VC. Icons shows a weak but significant ($p < 0.05$) correlation between preference and TTF ($\rho = 0.16$) and between preference and VC ($\rho = 0.13$). No linear correlations have been found between preference and TTF or VC in toys.

Gaze Pattern Differences

Table 1 analyses the independent variable TTF with all the factors [gender, character, color, and eye detail (see **Figure 1**, left column)] for icons. The gender factor [F (9.067), $p = 0.003$] presented a significant main effect ($p < 0.05$). There was no significant interaction between factors. The fixation time (s) differed significantly between boys (mean = 0.546, std = 0.707) and girls (mean = 0.383, std = 0.434). The independent variable VC was also analyzed with all the factors [gender, character, color, and eye detail (see **Figure 1**, left column)] for icons. There was presented a significant main effect ($p < 0.05$) between factors. Gender*Character interaction [F (3.856), $p = 0.004$], Gender*Color [F (2.388), $p = 0.050$], Character*Eye detail [F (1.902), $p = 0.018$], and Color*Eye detail [F (3.708), $p = 0.000$].

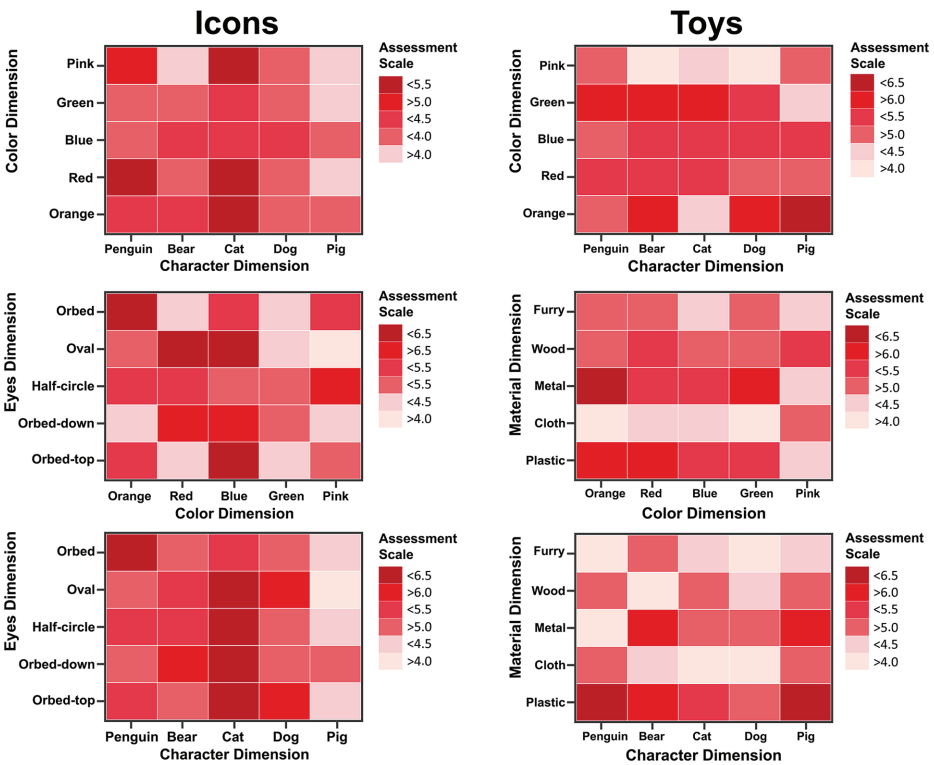

FIGURE 5 | Graphs of results for the assessment of the design dimensions of the icons **(left column)** and toys **(right column)**.

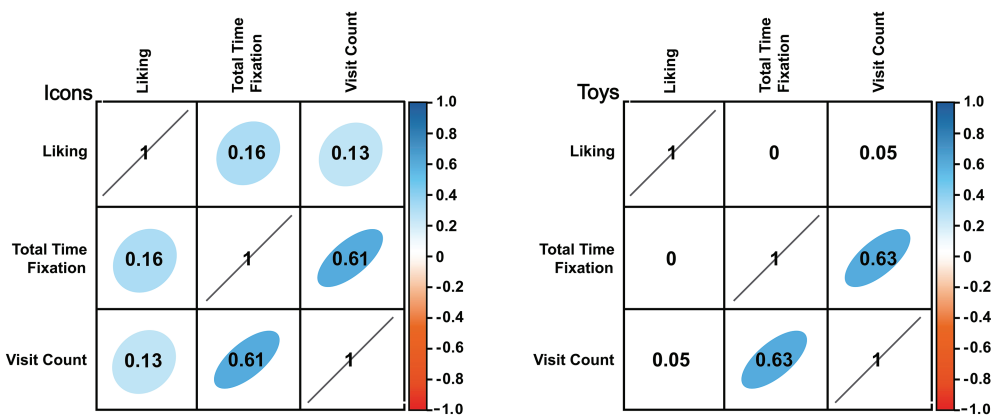

FIGURE 6 | Correlations between liking and visual attention. Number in the table shows the Pearson correlation coefficient, and the background is highlighted from red to blue in case of $p < 0.05$. Figure result for icons in left side and figure results for toys in right side.

Table 2 shows the analysis of the independent variable TTF with all the factors [gender, character, color, and material (see **Figure 1**, right column)] for toys. Material factor [F (2.461), $p = 0.044$] presented a significant main effect ($p < 0.05$). There was no significant interaction between factors. The fixation time (seconds) differed significantly between metal (mean = 0.898, std = 1.252), furry (mean = 0.696, std = 1.134), plastic (mean = 0.604, std = 1.090), wood (mean = 0.555, std = 0.827), and cloth (mean = 0.498, std = 0.630). The final analysis was made for the independent variable VC with complete factors [gender, character, color, and material (see **Figure 1**, right column)] for toys. Gender factor [F (2.461), $p = 0.044$] presented a significant main effect ($p < 0.05$). The visit count (times) differed significantly between boys (mean = 2.023, std = 3.14) and girls (mean = 1.491, std = 1.427). There was no significant interaction between factors.

TABLE 1 | Statistical result of multivariable ANOVA (MANOVA) for independent variables for icons.

Source	*SS*	*dF*	*MS*	*F*	*p*
Total time fixation					
Gender	3.529	1	3.529	9.067	**0.003***
Character	1.561	4	0.390	1.003	0.405
Color	1.375	4	0.344	0.883	0.473
Eye detail	0.930	4	0.233	0.598	0.665
Color*Eye detail	12.429	16	0.777	1.996	**0.011***
Visit count					
Gender*Character	30.573	4	7.643	3.856	**0.004****
Gender*Color	18.932	4	4.733	2.388	**0.050****
Gender*Eye details	6.302	4	1.576	0.795	0.529
Character*Color	17.839	16	1.115	0.563	0.912
Character*Eye detail	60.304	16	3.769	1.902	**0.018****
Color*Eye detail	117.590	16	7.349	3.708	**0.000****

*R Squared = 0.195 (*Adjusted R Squared = 0.050). R Squared = 0.226 (**Adjusted for R Squared = 0.086).*

TABLE 2 | Statistical result of MANOVA for independent variables for toys.

Source	*SS*	*dF*	*MS*	*F*	*p*
Total time fixation					
Gender	2.324	1	2.324	2.182	0.140
Character	8.836	4	2.209	2.074	0.082
Color	2.919	4	0.730	0.685	0.602
Material	10.484	4	2.621	2.461	**0.044***
Visit count					
Gender	34.401	1	34.401	4.414	**0.036****
Character	22.289	4	5.572	0.715	0.582
Color	46.938	4	11.734	1.506	0.199
Material	20.304	4	5.076	0.651	0.626

*R Squared = 0.147 (*Adjusted R Squared = 0.017). R Squared = 0.132 (**Adjusted for R Squared = 0.000).*

TABLE 3 | Analysis of the first four and last four dwells in each trial in the 8-AFK task.

Stimulus	Visit set	# of visits to chosen stimulus (ms)	Chosen stimulus total fixation time (ms)	Chosen stimulus is top fixation time (%)	Chosen stimulus within top two fixation time (%)
Icons	First four	0.607 (0.714)	178 (295)	23.0	32.8
	Last four	1.410 (0.761)	906 (678)	67.2	82.0
Toys	First four	0.627 (0.828)	172 (297)	15.2	27.1
	Last four	1.610 (0.891)	1,167 (799)	71.2	84.8

# of visits and total fixation time are shown using mean and standard deviation.

Recognizing the Choice With Visual Attention

Table 3 analyzes the gaze pattern during the four first and four last visits in both icons and toys. The number of visits and the total fixation time of the stimulus (icon and toy) chosen were higher in the last four visits than in the four first visits in both cases. Moreover, the chosen stimulus is the one with the longest fixation time during the last four visits, 67.2% of times for icons and 71.2% for toys. These results are considerably higher than the fixation time computed in the first four visits (23.0 and 15.2%, respectively). In addition, the chosen stimulus is within the top two stimuli with highest fixation time in 82.0 and 84.8% of times for icons and toys, respectively.

Analysis of Distractors

Figure 7 shows the proportion of total fixation time during the task that has each stimulus in the last 3 s before the decision-making moment. The data for the version of the icon tasks and toys were plotted separately, collapsing all participants and trials. In both cases, the five stimuli most viewed (the chosen one and the first four distractors) are relatively close 3 s before the decision-making instant. For toys, between 2.5 and 1.5 s before the decision, the future choice and first distractor grow in terms of proportion of TTF. In the last 1.5 s, all distractors decrease, meanwhile, the choice highly increases their TTF overtaking the first distractor. The icons follow the same patterns, but the moment when the choice overtakes the first distractor is 1 s before instead of 1.5.

DISCUSSION

The purpose of this research is to analyze the use of visual attention for evaluating children preferences, allowing to evaluate the decision-making processes beyond the classical self-report method. **Figure 5** shows the self-assessment preference of each of the stimuli presented and obtained in verbal report of task 2. This assessment helped to understand the implicit perception of design dimensions for icons and toys. The assessment revealed which elements were more liked or less liked by their aesthetic or active elements, including emotional ones (Green-Armytage, 2006; Hertenstein et al., 2013; Helo et al., 2014; Joško-Brakus et al., 2014; Kareklas et al., 2014). However, these evaluations are not capable of knowing to know information beyond the implicit perception of children. Using the information extracted from eye-tracking. A factor analysis was performed where the

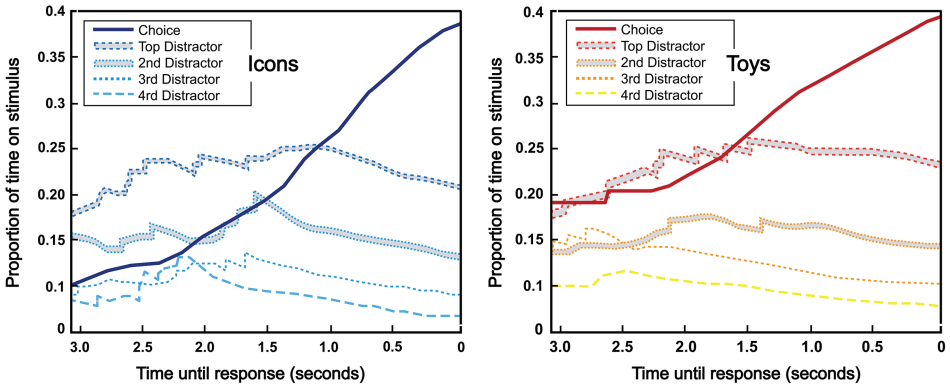

FIGURE 7 | Plots of the proportion of time extracted by chosen stimulus or distractor stimulus by eye-tracking (ranked by total fixation time). Plot result for icons choice and distractor (left) and plot result for toys choice and distractor (right).

fixation and visit variables could provide more information about the evaluation, mainly which elements were the most observed or most visited by the children. The first result observed for icons assessment with the TTF variable was the difference between how boys and girls perceiving the icons considering all the design dimensions. Boys on average spent 0.55 s observing the icon, while girls spent only 0.38 s. The second interesting result was how the VC variable on the icons revealed that the gender determines an interaction between design dimensions (color, eye-detail, and character). Boys and girls visit each icon differently depending on the design dimensions. These two results reveal deeper information about the icon assessment. Without having to ask the children which dimensions are the most liked, we can know which is the most observed and which is the most visited in the decision-making process. Also, the other factor analysis was made with the variables of TTF and VC for toys assessment. The first result observed for toys assessment with the TTF variable was the difference between how the material determines the fixation time. Metal is the most viewed, followed by furry and the least seen is the cloth material. The final analysis for this information using the variables extracted from the eye movement was VC. In the toy's assessment, the gender determined the number of visits that were made by the children. Boys visited a toy 2 times on average, while girls generally visited toys only 1.5 times on average. These two results reveal information that supports how the children were able to determine their choice of which toys were most liked. The material was a design dimension that caught their attention (Kwon et al., 2002; Lin, 2010; Festila and Chrysochou, 2018) and how boys need to visit more times than girls to do a decision-making. The results obtained using the traditional methods of icons and toys assessment were enhanced with the use of the data extracted from eye movement. This shows how the use of implicit measures can give deeper insights of the elements that were the determining factors in decision-making, as well as show the differences in behavior that a sample of people can have, in this study, gender was a determining factor.

In the present study, the method to recognition of decision-making with eye movement contribute beyond self-report was further explored. The 8-AFC task (Glaholt et al., 2009; Glaholt and Reingold, 2012) was using in multi-stimuli arrays for understanding the effect of eye movements and selection during preference process for children behavior. This task provided information on children's gaze behavior, providing additional insights that those already extracted in the analysis above. The information extracted from the two variables of eye movement and the design dimensions assessment were the base of this study. We explore the recognition level of the liking choice of 8-AFC using the visual attention patterns. To this propose, two sets of time-windows were analyzed: the first four visits and the last four visits. The results show that the first four visits were not able to recognize the future choice of the children, achieving 23.0 and 15.2% in icons and toys, respectively. Therefore, the results indicate that the preference for an item of the children is not correlated with the visual attention on the first seconds of exploration. On the other hand, the TTF of the last four visits allow to recognize the choice of a participant in 67.2 and 71.2% of the cases, which is considerably higher that the chance level in an 8-class problem (chance = 12.5%), assuming that the stimuli with higher TTF in this time-windows is the chosen one. Moreover, the final choice is taken from the top two stimuli with higher TTF in the 82.0 and 84.8% (in icons and toys, respectively) of times during the last four visits, in contrast to 32.8 and 84.8% when the first four visits are analyzed. **Table 3** shows the VC and TTF metrics of the chosen stimulus, where the values are always higher in the last four visits than in the first four for both icons and toys. The evolution of the percentage of TTF that each stimulus reaches during the 8-AFC task was also analyzed to characterize the choice dynamics and a decision is made in children's visual attention. **Figure 7** shows, in a graphic representation, the choice and the first four distractors in timeline of 3 s before the instant when the decision is made. Between 2.5 and 1.5 s before a decision is made, the choice and first distractor increase their accumulated TTF. The second distractor also appears but smoothly. In the case of icons, this phase was finalized 1 s before the decision. This suggests that, within these time windows, the subject is evaluating between 2 and 3 choices.

Finally, from this point of view, the accumulated TTF of choice overtakes the first distractor, and it in this time window where the decision is matured. This process takes 1 s for icons and 1.5 s for toys. It suggests that the decision-making process regarding toys takes more time, probably derived from the fact that toys are more complex stimuli and need more mental effort. This time can be used as an implicit measure of the effort needed to make a decision, and can help future designers, complementing classical self-reports.

The findings of this paper open possibilities to combine traditional self-report and eye movement techniques contribute with techniques that dive beyond self-report, and how this method reveal relevant information of people's behavior. The results of the first task of the experiment show similar results in the selection of the preference among different distractors (Shimojo et al., 2003; Simion and Shimojo, 2006, 2007; Glaholt and Reingold, 2009, 2012) and repeats the findings of Glaholt and Reingold (2012) and Mitsura and Glaholt (2014), where chosen stimuli dynamics can become an automatic recognition model using children eye movements. The result show of the second tasks show the analysis complexity that the assessment of the design dimensions stimuli can represent, this was addressed in a way such that the aesthetic implications or attributes such as color, material, or textures (Kwon et al., 2002; Green-Armytage, 2006; Lin, 2010; Hertenstein et al., 2013; Helo et al., 2014; Joško-Brakus et al., 2014; Kareklas et al., 2014; Festila and Chrysochou, 2018) could be observed through the fixation and visits.

However, it is still possible to go deeper into studies that focus on determining the relevance of each of these elements in decision-making and the heuristic recognition theory. The assessment results of icons and toys preference feed the information described by Pachur et al. (2011) on familiarity and inference in decision-making. Also, the main idea of this paper was to use simple stimuli that children could make quick and simple choice, following the notion presented by Marewski et al. (2009) and Arkes et al. (2016) for the consistency and simplicity in cognitive process. Finally, this type of paper contribution helps to understand human behavior and regardless of certain restrictions that a self-report may have in research of this nature (Song et al., 1994; Chambers, 2002; Sturgess et al., 2002; Kuijpers et al., 2014), we can continue to create relationships with adjacent theories and methods.

CONCLUSIONS

The current paper gives a relevant empirical result of a method that contributes to a better knowledge of the decision-making process in children, providing an interesting technique that goes beyond self-reports. Compared to other methods that use neuroscience tools, this one has a low complexity of implementation and good accessibility due to the type of technology that is required. Furthermore, this paper presents the implementation of our method with a sample of subjects, specifically children, who pose different challenges in order to analyze their behavior. As highlighted in several previous works, the use of eye-tracking can help to have an implicit measurement that can be used as an alternative or a complement to the collection of traditional data based on explicit measures by self-reporting or questionnaires. Future studies are planned to work with a bigger sample size, and other age segments, to confirm the results obtained in the present work.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because this experiement has a raw data and process in Matlab and SPSS data base. Requests to access the datasets should be directed to jcrojasl@tec.mx.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Universitat Politecnica de Valencia. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

All authors have contributed to the manuscript as follows: J-CR designed the study and supervised the whole study. JM-M conducted the eye-tracking raw data. J-CR and MC conducted the statistical analyses. J-CR, JM-M, and JMAA wrote the original manuscript. MC revised the manuscript. All authors assisted in the revision process, read, and approved the final manuscript.

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Emotional State During Tasting Affects Emotional Experience Differently and Robustly for Novel and Familiar Foods

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Emotional state during food consumption is expected to affect food pleasantness. We hypothesize that a negative emotional state reduces food pleasantness and more so for novel foods than for familiar foods because novel foods have not yet been associated with previous emotions. Furthermore, we expect this effect to be stronger when judging the food again from memory without tasting. We induced a positive emotional state in 34 participants by telling them that they earned a monetary bonus and induced a negative emotional state in 35 other participants by subjecting them to a social stress test. After this emotion induction, both groups tasted and rated a (for them) novel soup (sumashi soup) and a familiar soup (vegetable soup). Several explicit and implicit measures of food pleasantness (rated valence, EsSense25, willingness-to-take-home and sip size) indicated that while the negative emotion group did not experience the soups as less pleasant than the positive emotion group, there was an interaction between food familiarity and emotional group. The positive emotion group experienced novel and familiar soups as equally pleasant, whereas the negative emotion group experienced the novel soup as relatively unpleasant and the familiar soup as pleasant. The latter result is consistent with a comforting effect of a familiar taste in a stressful situation. This effect remained in the ratings given 1 week later based on memory and even after retasting. Our results show that emotional state affects food pleasantness differently for novel and familiar foods and that such an effect can be robust.

Keywords: emotional state, novelty, memory, food pleasantness, emotion

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INTRODUCTION

Food judgments (as probed by, e.g., ratings of food preference or liking, food pleasantness, food choice, and eating behavior) depend not only on the quality of the taste but also on the emotional state during food consumption, the social–emotional context in which the food is consumed, and already existing associations between food and emotion (Desmet and Schifferstein, 2008; Salvy et al., 2008). Food associations are related to regional food habits, different food cultures, and food traditions in the family.

The effect of ambiance on food intake and food choice was reviewed by Stroebele and De Castro (2004). They define ambiance as a context of environmental stimuli and conclude that there are major influences of ambiance on eating behavior. The studies that they reviewed showed effects of social–emotional aspects of context, as well as effects of physical aspects of contexts [e.g., colors (Spence et al., 2010; Chen et al., 2018), sounds (Spence and Shankar, 2010; Woods et al., 2011), and/or odors (Herz et al., 2004)]. We assume that many of the reported context effects, especially the social–emotional context effects, influence food judgments through the induction of a certain emotional state. Below we review studies that examine the effect of emotional state on food experience in some more detail.

Birch et al. (1980) examined the effects of pairing positive experiences with snack foods on children's liking of the foods. In their study, the same snack foods were served to children (1) as a reward, (2) by a friendly adult, (3) in a non-social context, or (4) at normal snack time. Children's liking ratings were higher on snack foods in the two emotionally positive contexts (as a reward or by a friendly adult) than in the other contexts, indicating that the liking of snack foods was affected by emotion. Siegel and Risvik (1987) examined the effect of positive and negative mood on acceptance ratings of an almond dairy bar in adulthood. They induced different moods by asking participants to indicate their current state using questionnaires that contained either positively formulated statements such as "I feel great" (positive mood group) or negative statements such as "I feel weak" (negative mood group). They found that participants from the positive mood group reported significantly higher acceptance of the almond dairy bar than those in the negative group.

Kuenzel et al. (2011) aimed to induce different emotional states using video clips to investigate the effect of emotional state on food preference and liking. For 5 consecutive days, participants watched 4- to 5-min positive video clips (two different positive states: one active and one relaxed) or a neutral video clip. Two different novel uncolored drinks were developed for this study: a generally liked drink and a more neutral drink. Participants were served the liked or the neutral drinks just before the start of the film clips and were instructed to finish them by the end of the clips. The study showed an interaction between type of drink (neutral and liked) and emotional state (active, relaxed, and neutral), indicating that liking ratings of the liked drink were lower in the relaxed condition than in the neutral condition. Thus, this study shows a (modest) effect of emotional state affecting liking scores of flavored drinks, be it not simply in the direction of an emotional state that was intended to be positive leading to higher liking. The authors suggest that the reason for this effect might be that participants' attention may have been divided when being in a positive state, leading to a tendency to score toward the middle of the liking scales, which resulted in relatively low liking scores for the liked drink.

Walsh and Kiviniemi (2014) used an "implicit priming paradigm" to create one of three emotional associations (positive, negative, or neutral) to images of fruit. This paradigm involves repeated presentation of sequential pairs of a positive, negative, or neutral image or word followed by an image of fruit. Twenty of these pairs were interspersed among a total of 230 images that were presented to each participant. At the end of the experiment, participants were asked to choose one among a selection of apples, bananas, and granola bars. Those in the positive condition were more likely to select fruit compared to those in either the neutral or negative condition.

All the studies discussed above indicate that emotional state can affect experienced food pleasantness and liking. They all used familiar foods as stimuli, except for the study by Kuenzel et al. (2011), in which only unfamiliar stimuli were used. We think that food familiarity is a key factor that may interact with emotional state when experiencing and judging food. When tasting a food for the first time (a novel food), effects of emotional state may be more pronounced than when tasting a familiar food because there is no influence yet of existing associations. Knowledge about such effects in the absence of prior existing associations is important, for instance, when introducing new products to the market or in medical settings where patients need to consume specific foods, supplements, or medicines. However, we are not aware of research exploring whether the effect of emotional state on food pleasantness indeed differs between novel and familiar food.

In addition, the majority of studies on the effect of emotional state or context focus on the instantaneous effect on food pleasantness. However, Köster and Mojet (2015) argued that the role of memory is probably much more important than the "first impression" experience that is commonly investigated. They emphasized that products should be tested for the emotions they evoke before, during, a few hours after, and a week (or even longer) after consumption, to obtain a more complete picture of the experience of the product.

In the current study, we evaluate how novel and familiar foods (two types of broths, from now on referred to as "soups") are affected by emotional state during tasting (positive/negative), both instantaneously and a week later. We asked participants to come to the laboratory twice, separated by an interval of 1 week; we refer to the first day as Day 1, and to the second day a week later as Day 2. On Day 1, participants were asked to taste and rate a novel soup and a familiar soup. Before tasting and rating the soups, we induced a positive emotional state in half of the participants, and we induced a negative emotional state in the other half. On Day 2, participants underwent two separate sessions. In the first session, participants were asked to rate the same soups as tasted and judged on Day 1, but without tasting (i.e., from memory). In the second session, they rated the same soups again, but this time with actual tasting. The effect of emotional state on food experience of novel and familiar soups was not only measured by using self-report [valence ratings; EsSense25 questionnaire (Nestrud et al., 2016) that probes 25 emotions associated with food], but also by using behavioral measures, namely, sip size and willingness-to-take-home. These measures are of a more implicit nature, and expected to support the self-report of valence ratings (Lagast et al., 2017; Kaneko et al., 2018).

The following hypotheses are tested:

(1) Overall experienced food pleasantness, as reflected in the valence ratings and the EsSense25, is lower when tasting

soups in a negative emotional state than in a positive emotional state.
(2) This effect is stronger for the novel soup than for the familiar soup.
(3) Differential effects of emotional state on novel and familiar soups will be stronger a week later when the actual taste of the soup is not available. This is because measures of experience will then only be based on memory, where the novel soup has only been associated with the experience of the (emotional) tasting session in the laboratory, and the familiar soup is also associated with other, previous food experiences.
(4) When participants subsequently taste the soups again, the effect mentioned under (3) is reduced, because experience is no longer based on memory alone.
(5) The behavioral measures of sip size and willingness-to-take-home show a similar pattern of results compared to subjective ratings.

In summary, this study will inform us about the interaction between emotional state and food familiarity on food experience, both during initial tasting and a week later.

MATERIALS AND METHODS

Participants

A total of 70 healthy participants (19 men, 51 women) were recruited for this study. Exclusion criteria were food allergies or special diets. One of the male participants dropped out from the study. Data from this participant were excluded from all analyses, leaving us with data of 69 participants. All participants had the Dutch nationality and were between 19 and 63 years old, with an average of 48.4 years and a standard deviation of 10.4 years. Participants were recruited through the participant pool of the research institute where the study took place (TNO) and received a basic monetary reward of 30 Euros per participant to compensate for time and travel costs. On top hereof, and unknown to them beforehand, participants in the positive emotional state group received a 5 Euro bonus. Before participating in this study, all participants signed an informed consent in accordance with the Helsinki Declaration of 1975 as revised in 2014 (World Medical Association, 2014). The study was approved by the TNO Institutional Review Board. After signing the informed consent, they were randomly assigned to the positive emotional state group (34 participants: 10 men, 24 women, average age of 49.2 years) or the negative emotional state group (35 participants: 8 men, 27 women, average age of 47.7).

Sip size data were not complete for three participants (one from the positive group, two from the negative group) and were thus left out in the analysis on sip size.

We also recorded physiological data. These recordings failed for two participants (one from the positive group and one from the negative group) and were thus left out in the analyses on the physiological data.

Materials

Test Stimuli

Vegetable and sumashi soup were selected as familiar and novel soups, respectively. Vegetable soup was prepared using vegetable bouillon cubes (Maggi, Nestlé, Switzerland) following the instruction on the package. Sumashi soup is a traditional Japanese transparent soup. It was prepared by mixing 5.0 g of seaweed broth (Riken Vitamin, Japan), 20.0 g of soy sauce (Kikkoman, Japan), 5.0 g of cooking sake (Wadakan, Japan), and 1.0 g of sea salt with 750 mL of hot water. The two soups were always prepared in the same way each morning and kept at approximately 60°C until they were served. Before serving the soups, a selection of regular drinks (apple juice, orange juice, yogurt drink, milk, buttermilk, rooibos tea, black tea, cola), diluted vinegar (50% vinegar, 50% water), and water were served in semirandomized order. This was done to answer other research questions (Kaneko et al., 2019). All soups were served in white plain cups, in portions of 50 g. At the end of Day 2 of the experiment, 100 g of each of the two soups was given to further assess the emotions evoked by tasting each soup.

Valence Scale

SAM pictures (Bradley and Lang, 1994) with nine-point scales were used for valence self-report ratings. The nine-point scale was positioned in the appropriate location at the bottom of each SAM scale, where the most leftward (most unpleasant) and the most rightward (most pleasant) parts of the scale were translated into values of 1 and 9, respectively. With respect to valence, participants were asked how pleasant their experience with the soup was, with the manikin on the right indicating a very pleasant experience and the manikin on the left a very unpleasant experience. Participants were instructed that they should try to answer quickly, without thinking too long.

EsSense25 Questionnaire

Besides valence scales, the EsSense25 (Nestrud et al., 2016) was used to obtain self-reported emotions evoked by experiencing the two soups. The EsSense25 is a shorter version of the EsSense Profile® (King and Meiselman, 2010), which was developed to measure emotions associated with foods. Each of 25 emotional terms (*loving*, *nostalgic*, *good*, *good natured*, *joyful*, *bored*, *secure*, *happy*, *warm*, *disgusted*, *pleasant*, *active*, *satisfied*, *aggressive*, *guilty*, *calm*, *free*, *understanding*, *enthusiastic*, *interested*, *tame*, *adventurous*, *wild*, *mild*, and *worried*) was assessed on a five-point scale ranging from 1 (not at all) to 5 (very much).

Behavioral Measures

For the behavioral measures, sip size and willingness-to-take-home were recorded. To measure sip size, the exact weight of each soup including the cup was measured before the participant took a sip. After finishing the experiment, the cups with the remainder of each soup were weighed again to determine the sip size.

A modified rating scale of willingness-to-take-home (Wichchukit and O'Mahony, 2010) was used in this study. While in the original scale participants would be asked which soup as used in the experiment they wanted to take home as a reward, we asked participants how many cups of each soup they

would want to take home after the experiment with a maximum number of 6 cups (e.g., 1 sumashi soup and 5 vegetable soup). Participants could choose fewer than 6 cups in total (e.g., none, or two sumashi soups and three vegetable soups).

Physiological Recording Equipment (Electrodermal Activity and Electrocardiogram)

Electrodermal activity [EDA; for skin conductance level (SCL)] and electrocardiogram [ECG; for interbeat interval (IBI), which is the inverse heart rate] were measured to assess whether the experimental induction of emotion was effective in case we would not find any effect of emotion. EDA and ECG were recorded using an Active Two MkII system (Biosemi B.V., Amsterdam, the Netherlands), with a sampling frequency of 512 Hz. SCL was measured by placing gelled electrodes on the fingertips of the index finger and the middle finger of the non-dominant hand. ECG electrodes were placed on the right clavicle and on the lowest floating left rib. SCL was measured by placing gelled electrodes on the fingertips of the index finger and the middle finger of the non-dominant hand. Electroencephalogram (EEG) was recorded as well, for different research questions (Kaneko et al., 2019).

Emotional State Induction

On Day 1, participants underwent either one of two types of emotional state induction, depending on the group they were assigned to. To induce a positive emotional state, participants received a message on the screen that they would receive an extra monetary bonus for participating in the experiment and that after tasting and judging the second soup they would receive the instruction to flip a card on the table that would tell them the exact amount of this bonus. This message was displayed just before displaying the name of the first soup. After tasting and judging the soups, the message to now flip the card was displayed. Participants flipped the card telling them that the amount of the bonus was 5 Euros. They received this bonus at the end of the experiment. To induce a negative emotional state, we used a modified Sing-a-Song Stress Test, which has been shown to induce profound social stress (Brouwer and Hogervorst, 2014; Brouwer et al., 2017; Toet et al., 2017). Just before the first soup, a message was displayed that they would receive the instruction to sing a song out loud after tasting and judging the second soup. This instruction was given as announced, and participants started singing a song. The aim of these emotion induction procedures was to induce emotions that were as different as possible with respect to pleasantness in the two groups, while keeping other elements (such as receiving an announcement about an exciting task to perform after tasting) as similar as possible.

Experimental Design and Procedure

Participants came to the laboratory twice. There were minimally 5 days and maximally 8 days (on average 6.97 days) between the first (Day 1) and the second (Day 2) recording session.

General Procedure Day 1

After participants arrived at the laboratory, the experimental procedure was explained by the experimenter. They were informed that they were going to take part in a study on food experience, in which they would taste and judge drinks and soups. Participants were not told about the emotion induction. After the explanation of the study, participants signed the informed consent and, unknown to them, were randomly assigned to the positive or negative emotional state group. Electrodes for measuring EDA, ECG, and EEG were attached, and participants were asked to sit comfortably in front of a computer screen. Participants were instructed how to take one sip and practiced an experimental trial. At this time, when the participant was in the negative emotional group, one of experimental leaders came in, pretending to be a next participant who arrived at the laboratory earlier than the appointed time. The other experimental leader asked the fake participant to stay in the same laboratory room to wait for the previous participant to finish the experiment. Thus, the fake participant was in the room during the whole experiment for the negative emotional state group. In the positive emotional state group, only the experimenter was present. Participants filled out a general questionnaire on demographic details and current emotional state. A tasting and rating trial (schematically depicted in the top left of **Figure 1**) went as follows. First, the name of the test sample was presented on the screen. This was the sign for the experimenters to place the appropriate cup in front of the participant. After 5 s, the name of the test sample disappeared, which was the sign for the participant to take one sip. After taking the sip, participants sat still and looked at a blank white screen. Forty seconds after the name had appeared on the screen, the self-report SAM rating scales appeared. After entering the scores, the next trial started. This procedure was repeated until all drinks had been served (depicted in gray in **Figure 1**). Immediately after, the group-dependent emotional state was evoked through an instruction screen as outlined above. Then, participants in both groups were served the two soups following the same procedure as before and after rating the second soup performed the task as instructed (i.e., either flip the reward card or sing a song). Sumashi soup was presented as "Asian soup" to participants. Half of the participants first tasted the vegetable soup and half the sumashi soup. After participants completed the task, another 100 g of the two soups was served to all participants in the same serving order as they had tasted and rated before. This time participants could taste more than once and were asked to more elaborately self-report their emotions evoked by tasting each soup using the EsSense25. After filling out the EsSense25 questionnaires, participants were asked to answer whether they were familiar with the taste of "Asian soup" and to write down the name of the soup if they knew the name or wanted to make a guess. In the end of the experiment, we asked participants how many cups of vegetable soup and Asian soup they would want to bring home if they would receive them for free (with a maximum of 6 in total). They did not actually receive such cups of each soup to prevent them to consume the soups (more than they usually would do) the days preceding Day 2.

General Procedure Day 2

The session on Day 2 was divided into two parts and was conducted without any physiological measures and without emotion induction. The schematic experimental procedure is summarized in the bottom half of **Figure 1**. First, participants

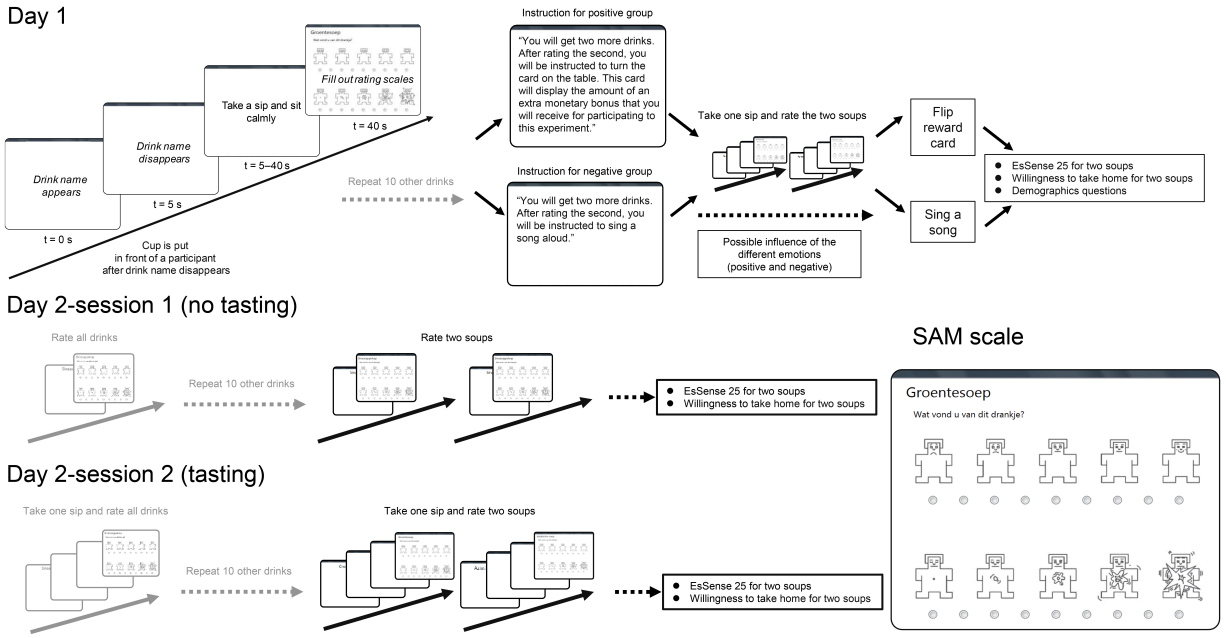

FIGURE 1 | Schematic overview of an experimental trial and of the experimental procedure in Day 1, Day 2–1, and Day 2–2. At the bottom-right, a rating screen is depicted, showing the small circles below the SAM scales that participants clicked in order to give their responses, upon which a new trial started. In Day 1, participants are separated into two groups, with either positive or negative emotion induction. Emotion induction occurred before tasting and rating two soups. In Day 2–1 and Day 2–2, all participants followed the exact same procedure. Parts of the procedure highlighted in gray served to answer other research questions (Kaneko et al., 2019).

were asked to sit in front of a screen and rate each drink and soup without tasting them, only relying on their memorized experience from 1 week ago. The name of the drink or soup appeared on the screen, followed by the SAM scales as on Day 1, but without the 40-s blank screen period in between. For each participant, the order of the drinks and soups was the same as on Day 1. Next, participants were asked to rate their emotions with the two soups using the EsSense25, i.e., based only on their memory of the taste and the emotions they had encountered a week before. Then, they were asked again for the two soups they would want to take home in the same manner as on Day 1. After this first session of Day 2 (referred to as Day 2–1), the second session of Day 2 (Day 2–2) commenced. In this second session, the same procedure was repeated, but this time with tasting and rating the drinks and soups in exactly the same manner as on Day 1. This also included judging the soups using the EsSense25, while being provided with 100 g of each of the two soups. Finally, as on Day 1, we asked how many cups of vegetable soup and Asian soup they would like to take home. After they completed the experimental tasks in Day 2, the experimenters debriefed participants on the purpose of the study and the emotion induction procedures.

Data Processing and Statistical Analysis

Main Dependent Variables

Our main dependent variables reflecting food experience are valence ratings, EsSense25 ratings, sip size, and willingness-to-take-home.

Statistical analyses on dependent variables were conducted using SPSS version 25. To investigate the main effects and interactions of soup (familiar vegetable soup and novel sumashi soup), session (Day 1, Day 2–1, and Day 2–2), and emotional state (positive and negative), we performed mixed model analyses (maximum likelihood approach) with soup (2) and session (3) as within-subjects variables, and state (2) as between-subjects variable. For sip size, session involved two rather than three levels (Day 1 and Day 2–2) because participants did not take a sip in the Day 2–1 session.

For all statistical tests, we considered an α level of 0.05. Given that the EsSense25 features 25 variables, correction for multiple testing is in place. Therefore we also interpret these results within the light of the Bonferroni-corrected α level of 0.002. Least significant difference (LSD) *post-hoc* comparisons were performed to interpret any significant interactions that, in the case of EsSense25, survive the Bonferroni correction. This came down to *post-hoc* comparisons that elucidated state $\times$ soup interactions in six measures.

SCL and IBI

Custom-made MATLAB 2019a[1] algorithms were used to extract SCL and IBI. To examine the effect of the instruction that was intended to induce either positive or negative emotion on SCL and IBI, the following steps were followed. First, the EDA signal was bandpass filtered between 0.03 and 100 Hz. IBI,

[1]www.mathworks.com

defined as the temporal distance between R-spike (Appelhans and Luecken, 2006), was extracted from the ECG signal using custom-made algorithms. Next, for each participant, EDA was averaged across the 40 s starting at onset of the announcement of the first soup that was presented immediately after the message that induced the positive or negative emotion. The same was done for the last drink that was presented before the message that induced the positive or negative emotion. This latter value served as a baseline. After log transforming the values, the baseline was subtracted from the value obtained after the emotion induction. The same procedure was followed for IBI. An increase in emotional arousal would be reflected by decreased IBI (i.e., increased heart rate) and increased SCL (Brouwer and Hogervorst, 2014). We examined whether these differential values were indeed statistically different from zero using one-sample *t*-tests. We also compared them between the positive and negative emotional state groups by using two-sample *t*-test.

RESULTS

Verifying the Experimental Manipulations

Emotion Induction

Figure 2 shows the average difference of the mean SCL and the mean IBI before and after the positive emotion induction (announcement to flip a bonus reward card after tasting and rating two soups) and the negative emotion induction (announcement to sing a song after tasting and rating two soups). As expected, IBI decreased and SCL increased for both positive emotion induction [IBI: $t(32) = -2.61$, $p = 0.014$; SCL: $t(33) = 2.89$, $p = 0.007$] and for negative emotion induction [IBI: $t(32) = -4.14$, $p < 0.001$; SCL: $t(33) = 6.09$, $p < 0.001$]. This shows that both types of emotion inductions indeed elicited arousal. Two-sample *t*-tests indicated that elicited emotional arousal was even stronger for the negative emotion induction than for the positive emotion induction [IBI: $t(65) = 2.51$, $p = 0.015$; SCL: $t(65) = -3.70$, $p < 0.001$].

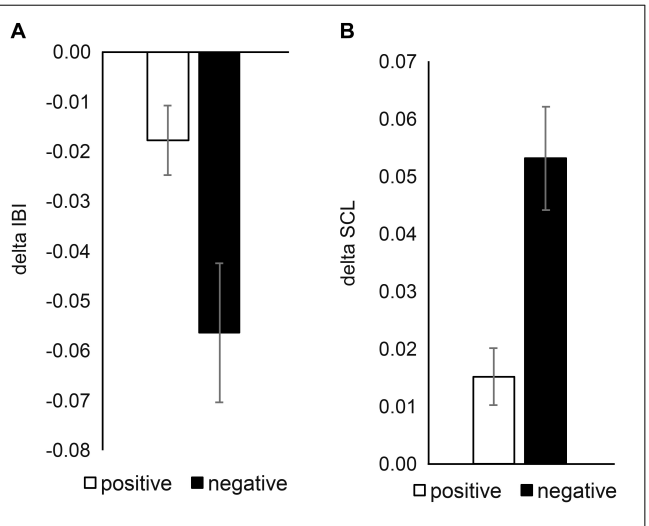

FIGURE 2 | Mean delta values for **(A)** IBI and **(B)** SCL between before and after announcement in positive emotional group and in negative emotional group. Error bars indicate standard error of the mean.

Novelty of Foods

None of the participants reported to have experienced the taste of sumashi soup before, and none of them were able to answer the question of what type of "Asian soup" had been used in this study, indicating that the sumashi soup can indeed be considered as a novel soup for all participants in this study.

Effect of Emotional State

Table 1 presents the results of the mixed-model analyses for each of the dependent variables. Significant effects are marked in light gray. **Table 2** presents *post-hoc* comparisons that elucidate significant soup × state interactions. In the following sections, we focus on the statistical results that are directly connected to our hypotheses.

Valence Ratings

Reported mean valence of each soup averaged across participants for each of the three sessions (Day1, Day2–1, and Day 2–2), each of the two emotional states (positive/negative), and each of the two soups (familiar/novel) is presented in **Figure 3**. There was no main effect of emotional state on valence ratings (Hypothesis 1) [$F(1, 69) = 0.09$, $p = 0.764$, $\eta_p^2 = 0.001$], but we found a significant interaction effect between emotional states and soups [$F(1, 345) = 20.90$, $p < 0.001$, $\eta_p^2 = 0.087$]. The *post-hoc* tests indicated that the novel soup was judged as less pleasant than the familiar soup in the negative emotional state, whereas there was no difference between the ratings of the two soups in the positive emotional state (first two columns in **Table 2**). *Post-hoc* tests also indicated that the familiar soup was judged as more pleasant in the negative than in the positive emotional state and that the novel soup was judged as less pleasant in the negative than in the positive emotional state (last two columns in **Table 2**) (Hypothesis 2). A lack of interaction between state, soup, and session indicates that this effect remains constant across sessions (Hypotheses 3 and 4).

Self-Reported Emotions (EsSense25)

Figure 4 shows the mean ratings for the 25 emotions of each soup averaged across participants for each of the three sessions (Day1, Day2–1, and Day 2–2) in each of positive and negative emotional state. As can be seen in **Table 1**, similar to what was found for valence ratings, there was no main effect of emotion (Hypothesis 1), whereas for nine out of 25 emotions the analyses revealed significant interactions between emotional states and soups (Hypothesis 2). Six of these nine emotions concerned positive emotions [*happy*, $F(1, 345) = 18.80$, $p < 0.001$, $\eta_p^2 = 0.109$; *pleasant*, $F(1, 345) = 11.75$, $p = 0.001$, $\eta_p^2 = 0.060$; *good*, $F(1, 345) = 10.10$, $p = 0.002$, $\eta_p^2 = 0.064$; *warm*, $F(1, 345) = 5.42$, $p = 0.020$, $\eta_p^2 = 0.043$; *enthusiastic*, $F(1, 345) = 4.68$, $p = 0.031$, $\eta_p^2 = 0.023$; *joyful*, $F(1, 345) = 4.61$, $p = 0.033$, $\eta_p^2 = 0.027$]. They all showed the same pattern as rated valence, namely, stronger positive emotions for the familiar soup than the novel soup,

TABLE 1 | Summary of the statistical data obtained with a mixed-model analysis for each of the dependent variables.

Dependent variables	Soup (familiar, novel)	State (positive, negative)	Session (Day 1, Day 2–1, Day 2–2)[a]	Soup × state	State × session	Soup × session	Soup × state × session
Valence	$F(1, 345) = 27.80$, $p < 0.001$, $\eta_p^2 = 0.112$	$F(1, 69) = 0.09$, $p = 0.764$, $\eta_p^2 = 0.001$	$F(2, 345) = 4.90$, $p = 0.080$, $\eta_p^2 = 0.122$	$F(1, 345) = 20.90$, $p < 0.001$, $\eta_p^2 = 0.087$	$F(2, 345) = 0.11$, $p = 0.896$, $\eta_p^2 = 0.003$	$F(2, 345) = 1.12$, $p = 0.328$, $\eta_p^2 = 0.039$	$F(2, 345) = 0.45$, $p = 0.635$, $\eta_p^2 = 0.016$
Sip size	$F(1, 198) = 5.11$, $p = 0.025$, $\eta_p^2 = 0.089$	$F(1, 66) = 0.26$, $p = 0.613$, $\eta_p^2 = 0.004$	$F(1, 198) = 5.18$, $p = 0.024$, $\eta_p^2 = 0.045$	$F(1, 198) = 7.59$, $p = 0.006$, $\eta_p^2 = 0.126$	$F(1, 198) = 0.37$, $p = 0.541$, $\eta_p^2 = 0.003$	$F(1, 198) = 0.52$, $p = 0.471$, $\eta_p^2 = 0.014$	$F(1, 198) = 1.59$, $p = 0.209$, $\eta_p^2 = 0.043$
Willingness-to-take-home	$F(1, 345) = 5.02$, $p = 0.026$, $\eta_p^2 = 0.017$	$F(1, 69) = 0.35$, $p = 0.557$, $\eta_p^2 = 0.005$	$F(2, 345) = 0.28$, $p = 0.753$, $\eta_p^2 = 0.040$	$F(1, 345) = 11.16$, $p = 0.001$, $\eta_p^2 = 0.036$	$F(2, 345) = 0.05$, $p = 0.955$, $\eta_p^2 = 0.007$	$F(2, 345) = 0.36$, $p = 0.697$, $\eta_p^2 = 0.021$	$F(2, 345) = 0.40$, $p = 0.670$, $\eta_p^2 = 0.023$
Active	$F(1, 345) = 3.59$, $p = 0.059$, $\eta_p^2 = 0.027$	$F(1, 69) = 0.52$, $p = 0.474$, $\eta_p^2 = 0.007$	$F(2, 345) = 1.93$, $p = 0.146$, $\eta_p^2 = 0.027$	$F(1, 345) = 2.01$, $p = 0.157$, $\eta_p^2 = 0.015$	$F(2, 345) = 0.31$, $p = 0.733$, $\eta_p^2 = 0.005$	$F(2, 345) = 1.53$, $p = 0.586$, $\eta_p^2 = 0.038$	$F(2, 345) = 0.43$, $p = 0.651$, $\eta_p^2 = 0.011$
Adventurous	$F(1, 345) = 86.37$, $p < 0.001$, $\eta_p^2 = 0.336$	$F(1, 69) = 0.14$, $p = 0.705$, $\eta_p^2 = 0.002$	$F(2, 345) = 0.35$, $p = 0.080$, $\eta_p^2 = 0.008$	$F(1, 345) = 0.00$, $p = 0.983$, $\eta_p^2 < 0.001$	$F(2, 345) = 1.64$, $p = 0.195$, $\eta_p^2 = 0.036$	$F(2, 345) = 0.54$, $p = 0.219$, $\eta_p^2 = 0.012$	$F(2, 345) = 0.30$, $p = 0.739$, $\eta_p^2 = 0.007$
Aggressive	$F(1, 345) = 58.07$, $p < 0.001$, $\eta_p^2 = 0.248$	$F(1, 69) = 3.41$, $p = 0.069$, $\eta_p^2 = 0.047$	$F(2, 345) = 1.73$, $p = 0.179$, $\eta_p^2 = 0.040$	$F(1, 345) = 2.09$, $p = 0.149$, $\eta_p^2 = 0.012$	F(2, 345) = 0.14, $p = 0.873$, $\eta_p^2 = 0.003$	$F(2, 345) = 1.46$, $p = 0.234$, $\eta_p^2 = 0.033$	$F(2, 345) = 0.19$, $p = 0.829$, $\eta_p^2 = 0.004$
Bored	$F(1, 345) = 5.95$, $p = 0.015$, $\eta_p^2 = 0.043$	$F(1, 69) = 0.54$, $p = 0.464$, $\eta_p^2 = 0.008$	$F(2, 345) = 0.01$, $p = 0.990$, $\eta_p^2 < 0.001$	$F(1, 345) = 4.54$, $p = 0.034$, $\eta_p^2 = 0.043$	$F(2, 345) = 0.45$, $p = 0.639$, $\eta_p^2 = 0.007$	$F(2, 345) = 0.37$, $p = 0.693$, $\eta_p^2 = 0.009$	$F(2, 345) = 1.36$, $p = 0.259$, $\eta_p^2 = 0.031$
Clam	$F(1, 345) = 45.03$, $p < 0.001$, $\eta_p^2 = 0.244$	$F(1, 69) = 0.02$, $p = 0.889$, $\eta_p^2 < 0.001$	$F(2, 345) = 1.37$, $p = 0.257$, $\eta_p^2 = 0.022$	$F(1, 345) = 0.27$, $p = 0.601$, $\eta_p^2 = 0.002$	$F(2, 345) = 1.82$, $p = 0.163$, $\eta_p^2 = 0.029$	$F(2, 345) = 1.62$, $p = 0.199$, $\eta_p^2 = 0.037$	$F(2, 345) = 0.21$, $p = 0.812$, $\eta_p^2 = 0.005$
Disgust	$F(1, 345) = 34.68$, $p < 0.001$, $\eta_p^2 = 0.127$	$F(1, 69) = 1.80$, $p = 0.184$, $\eta_p^2 = 0.025$	$F(2, 345) = 1.60$, $p = 0.203$, $\eta_p^2 = 0.058$	$F(1, 345) = 7.56$, $p = 0.006$, $\eta_p^2 = 0.031$	$F(2, 345) = 0.13$, $p = 0.878$, $\eta_p^2 = 0.005$	$F(2, 345) = 0.16$, $p = 0.853$, $\eta_p^2 = 0.006$	$F(2, 345) = 0.05$, $p = 0.953$, $\eta_p^2 = 0.002$
Enthusiastic	$F(1, 345) = 0.02$, $p = 0.885$, $\eta_p^2 < 0.001$	$F(1, 69) = 0.00$, $p = 0.998$, $\eta_p^2 < 0.001$	$F(2, 345) = 1.12$, $p = 0.327$, $\eta_p^2 = 0.023$	$F(1, 345) = 4.68$, $p = 0.031$, $\eta_p^2 = 0.023$	$F(2, 345) = 0.67$, $p = 0.512$, $\eta_p^2 = 0.014$	$F(2, 345) = 0.83$, $p = 0.439$, $\eta_p^2 = 0.029$	$F(2, 345) = 0.14$, $p = 0.870$, $\eta_p^2 = 0.005$
Free	$F(1, 345) = 3.44$, $p = 0.064$, $\eta_p^2 = 0.034$	$F(1, 69) = 0.25$, $p = 0.616$, $\eta_p^2 = 0.004$	$F(2, 345) = 0.02$, $p = 0.985$, $\eta_p^2 < 0.001$	$F(1, 345) = 3.44$, $p = 0.064$, $\eta_p^2 = 0.034$	$F(2, 345) = 0.55$, $p = 0.580$, $\eta_p^2 = 0.008$	$F(2, 345) = 0.46$, $p = 0.632$, $\eta_p^2 = 0.008$	$F(2, 345) = 1.17$, $p = 0.313$, $\eta_p^2 = 0.021$
Good	$F(1, 345) = 16.36$, $p < 0.001$, $\eta_p^2 = 0.099$	$F(1, 69) = 0.14$, $p = 0.711$, $\eta_p^2 = 0.002$	$F(2, 345) = 2.37$, $p = 0.095$, $\eta_p^2 = 0.036$	$F(1, 345) = 10.10$, $p = 0.002$, $\eta_p^2 = 0.064$	$F(2, 345) = 0.16$, $p = 0.854$, $\eta_p^2 = 0.002$	$F(2, 345) = 0.11$, $p = 0.894$, $\eta_p^2 = 0.003$	$F(2, 345) = 0.16$, $p = 0.855$, $\eta_p^2 = 0.005$
Good natured	$F(1, 345) = 23.99$, $p < 0.001$, $\eta_p^2 = 0.143$	$F(1, 69) = 0.90$, $p = 0.345$, $\eta_p^2 = 0.013$	$F(2, 345) = 5.74$, $p = 0.004$, $\eta_p^2 = 0.091$	$F(1, 345) = 1.23$, $p = 0.267$, $\eta_p^2 = 0.009$	$F(2, 345) = 1.11$, $p = 0.331$, $\eta_p^2 = 0.019$	$F(2, 345) = 0.41$, $p = 0.667$, $\eta_p^2 = 0.009$	$F(2, 345) = 0.92$, $p = 0.401$, $\eta_p^2 = 0.021$
Guilty	$F(1, 345) = 13.14$, $p < 0.001$, $\eta_p^2 = 0.094$	$F(1, 69) = 2.41$, $p = 0.125$, $\eta_p^2 = 0.034$	$F(2, 345) = 4.10$, $p = 0.017$, $\eta_p^2 = 0.057$	$F(1, 345) = 5.82$, $p = 0.016$, $\eta_p^2 = 0.044$	$F(2, 345) = 0.21$, $p = 0.808$, $\eta_p^2 = 0.003$	$F(2, 345) = 1.90$, $p = 0.151$, $\eta_p^2 = 0.044$	$F(2, 345) = 0.14$, $p = 0.871$, $\eta_p^2 = 0.003$

(Continued)

TABLE 1 | Continued

Dependent variables	Soup (familiar, novel)	State (positive, negative)	Session (Day 1, Day 2–1, Day 2–2)[a]	Soup × state	State × session	Soup × session	Soup × state × session
Happy	$F(1, 345) = 24.39$, $p < 0.001$, $\eta_p^2 = 0.142$	$F(1, 69) = 0.23$, $p = 0.631$, $\eta_p^2 = 0.003$	$F(2, 345) = 0.93$, $p = 0.397$, $\eta_p^2 = 0.015$	$F(1, 345) = 18.08$, $p < 0.001$, $\eta_p^2 = 0.109$	$F(2, 345) = 0.48$, $p = 0.621$, $\eta_p^2 = 0.008$	$F(2, 345) = 0.33$, $p = 0.722$, $\eta_p^2 = 0.008$	$F(2, 345) = 0.19$, $p = 0.828$, $\eta_p^2 = 0.005$
Interested	$F(1, 345) = 0.39$, $p = 0.532$, $\eta_p^2 = 0.002$	$F(1, 69) = 0.20$, $p = 0.653$, $\eta_p^2 = 0.003$	$F(2, 345) = 2.34$, $p = 0.098$, $\eta_p^2 = 0.038$	$F(1, 345) = 3.81$, $p = 0.052$, $\eta_p^2 = 0.023$	$F(2, 345) = 0.64$, $p = 0.527$, $\eta_p^2 = 0.011$	$F(2, 345) = 0.02$, $p = 0.985$, $\eta_p^2 < 0.001$	$F(2, 345) = 0.51$, $p = 0.601$, $\eta_p^2 = 0.016$
Joyful	$F(1, 345) = 5.79$, $p = 0.017$, $\eta_p^2 = 0.034$	$F(1, 69) = 0.62$, $p = 0.433$, $\eta_p^2 = 0.009$	$F(2, 345) = 2.14$, $p = 0.120$, $\eta_p^2 = 0.044$	$F(1, 345) = 4.61$, $p = 0.033$, $\eta_p^2 = 0.027$	$F(2, 345) = 0.95$, $p = 0.387$, $\eta_p^2 = 0.020$	$F(2, 345) = 0.55$, $p = 0.577$, $\eta_p^2 = 0.012$	$F(2, 345) = 0.11$, $p = 0.899$, $\eta_p^2 = 0.002$
Loving	$F(1, 345) = 23.52$, $p < 0.001$, $\eta_p^2 = 0.180$	$F(1, 69) = 0.00$, $p = 0.973$, $\eta_p^2 = .$	$F(2, 345) = 0.17$, $p = 0.840$, $\eta_p^2 = 0.003$	$F(1, 345) = 4.38$, $p = 0.037$, $\eta_p^2 = 0.039$	$F(2, 345) = 3.50$, $p = 0.031$, $\eta_p^2 = 0.057$	$F(2, 345) = 0.39$, $p = 0.680$, $\eta_p^2 = 0.006$	$F(2, 345) = 0.94$, $p = 0.393$, $\eta_p^2 = 0.015$
Mild	$F(1, 345) = 52.00$, $p < 0.001$, $\eta_p^2 = 0.258$	$F(1, 69) = 0.19$, $p = 0.668$, $\eta_p^2 = 0.003$	$F(2, 345) = 0.45$, $p = 0.639$, $\eta_p^2 = 0.008$	$F(1, 345) = 2.53$, $p = 0.113$, $\eta_p^2 = 0.017$	$F(2, 345) = 0.30$, $p = 0.745$, $\eta_p^2 = 0.005$	$F(2, 345) = 2.17$, $p = 0.116$, $\eta_p^2 = 0.052$	$F(2, 345) = 0.43$, $p = 0.651$, $\eta_p^2 = 0.011$
Nostalgic	$F(1, 345) = 109.62$, $p < 0.001$, $\eta_p^2 = 0.398$	$F(1, 69) = 0.94$, $p = 0.335$, $\eta_p^2 = 0.013$	$F(2, 345) = 0.59$, $p = 0.558$, $\eta_p^2 = 0.013$	$F(1, 345) = 3.40$, $p = 0.066$, $\eta_p^2 = 0.020$	$F(2, 345) = 1.84$, $p = 0.160$, $\eta_p^2 = 0.039$	$F(2, 345) = 2.34$, $p = 0.098$, $\eta_p^2 = 0.050$	$F(2, 345) = 0.45$, $p = 0.635$, $\eta_p^2 = 0.010$
Pleasant	$F(1, 345) = 9.56$, $p = 0.002$, $\eta_p^2 = 0.049$	$F(1, 69) = 0.00$, $p = 0.984$, $\eta_p^2 < 0.001$	$F(2, 345) = 0.26$, $p = 0.774$, $\eta_p^2 = 0.006$	$F(1, 345) = 11.75$, $p = 0.001$, $\eta_p^2 = 0.060$	$F(2, 345) = 0.09$, $p = 0.917$, $\eta_p^2 = 0.002$	$F(2, 345) = 0.11$, $p = 0.901$, $\eta_p^2 = 0.003$	$F(2, 345) = 0.25$, $p = 0.778$, $\eta_p^2 = 0.007$
Satisfied	$F(1, 345) = 24.79$, $p < 0.001$, $\eta_p^2 = 0.116$	$F(1, 69) = 0.00$, $p = 0.974$, $\eta_p^2 < 0.001$	$F(2, 345) = 3.49$, $p = 0.032$, $\eta_p^2 = 0.067$	$F(1, 345) = 1.42$, $p = 0.234$, $\eta_p^2 = 0.007$	$F(2, 345) = 0.81$, $p = 0.445$, $\eta_p^2 = 0.016$	$F(2, 345) = 0.48$, $p = 0.617$, $\eta_p^2 = 0.016$	$F(2, 345) = 0.97$, $p = 0.380$, $\eta_p^2 = 0.032$
Secure	$F(1, 345) = 33.69$, $p < 0.001$, $\eta_p^2 = 0.194$	$F(1, 69) = 0.51$, $p = 0.478$, $\eta_p^2 = 0.007$	$F(2, 345) = 1.53$, $p = 0.217$, $\eta_p^2 = 0.029$	$F(1, 345) = 1.32$, $p = 0.252$, $\eta_p^2 = 0.009$	$F(2, 345) = 1.89$, $p = 0.153$, $\eta_p^2 = 0.036$	$F(2, 345) = 1.12$, $p = 0.327$, $\eta_p^2 = 0.021$	$F(2, 345) = 2.31$, $p = 0.101$, $\eta_p^2 = 0.043$
Tame	$F(1, 345) = 32.04$, $p < 0.001$, $\eta_p^2 = 0.212$	$F(1, 69) = 1.05$, $p = 0.309$, $\eta_p^2 = 0.015$	$F(2, 345) = 0.26$, $p = 0.769$, $\eta_p^2 = 0.004$	$F(1, 345) = 0.09$, $p = 0.762$, $\eta_p^2 = 0.001$	$F(2, 345) = 0.38$, $p = 0.682$, $\eta_p^2 = 0.006$	$F(2, 345) = 0.35$, $p = 0.704$, $\eta_p^2 = 0.008$	$F(2, 345) = 2.31$, $p = 0.101$, $\eta_p^2 = 0.049$
Understanding	$F(1, 345) = 20.71$, $p < 0.001$, $\eta_p^2 = 0.190$	$F(1, 69) = 0.01$, $p = 0.913$, $\eta_p^2 < 0.001$	$F(2, 345) = 5.37$, $p = 0.005$, $\eta_p^2 = 0.067$	$F(1, 345) = 3.53$, $p = 0.061$, $\eta_p^2 = 0.038$	$F(2, 345) = 2.97$, $p = 0.052$, $\eta_p^2 = 0.038$	$F(2, 345) = 0.05$, $p = 0.950$, $\eta_p^2 = 0.001$	$F(2, 345) = 1.68$, $p = 0.188$, $\eta_p^2 = 0.031$
Warm	$F(1, 345) = 22.10$, $p < 0.001$, $\eta_p^2 = 0.155$	$F(1, 69) = 0.35$, $p = 0.554$, $\eta_p^2 = 0.005$	$F(2, 345) = 1.76$, $p = 0.174$, $\eta_p^2 = 0.024$	$F(1, 345) = 5.42$, $p = 0.020$, $\eta_p^2 = 0.043$	$F(2, 345) = 2.19$, $p = 0.113$, $\eta_p^2 = 0.029$	$F(2, 345) = 0.67$, $p = 0.513$, $\eta_p^2 = 0.017$	$F(2, 345) = 1.03$, $p = 0.358$, $\eta_p^2 = 0.025$
Wild	$F(1, 345) = 80.82$, $p < 0.001$, $\eta_p^2 = 0.316$	$F(1, 69) = 1.23$, $p = 0.272$, $\eta_p^2 = 0.017$	$F(2, 345) = 2.49$, $p = 0.084$, $\eta_p^2 = 0.056$	$F(1, 345) = 0.52$, $p = 0.471$, $\eta_p^2 = 0.003$	$F(2, 345) = 0.31$, $p = 0.732$, $\eta_p^2 = 0.007$	$F(2, 345) = 0.36$, $p = 0.697$, $\eta_p^2 = 0.008$	$F(2, 345) = 0.03$, $p = 0.974$, $\eta_p^2 = 0.001$
Worried	$F(1, 345) = 10.32$, $p = 0.001$, $\eta_p^2 = 0.077$	$F(1, 69) = 2.48$, $p = 0.120$, $\eta_p^2 = 0.035$	$F(2, 345) = 1.37$, $p = 0.257$, $\eta_p^2 = 0.021$	$F(1, 345) = 2.57$, $p = 0.110$, $\eta_p^2 = 0.020$	$F(2, 345) = 4.44$, $p = 0.012$, $\eta_p^2 = 0.066$	$F(2, 345) = 0.57$, $p = 0.568$, $\eta_p^2 = 0.012$	$F(2, 345) = 0.38$, $p = 0.682$, $\eta_p^2 = 0.008$

The significant main effects and interactions were highlighted in light gray. Variables below the dashed lines reflect the EsSence25 variables. [a]*There are only two levels of session for sip size (Day 1 and Day 2–2).*

TABLE 2 | Summary of LSD *post-hoc* comparisons that elucidate significant soup × state interactions.

Soup × state	Familiar positive vs. novel positive	Familiar negative vs. novel negative	Familiar positive vs. familiar negative	Novel positive vs. novel negative
Valence	$p = 0.706$	$p < 0.001$	$p = 0.005$	$p = 0.035$
Sip size	$p = 0.946$	$p = 0.014$	$p = 0.060$	$p = 0.517$
Willingness-to-take-home	$p = 0.449$	$p < 0.001$	$p = 0.006$	$p = 0.060$
Good	$p = 0.650$	$p < 0.001$	$p = 0.033$	$p = 0.226$
Happy	$p = 0.738$	$p < 0.001$	$p = 0.147$	$p = 0.007$
Pleasant	$p = 0.855$	$p < 0.001$	$p = 0.057$	$p = 0.064$

The significant effects are highlighted in light gray. Variables below the dashed lines reflect the EsSence25 variables.

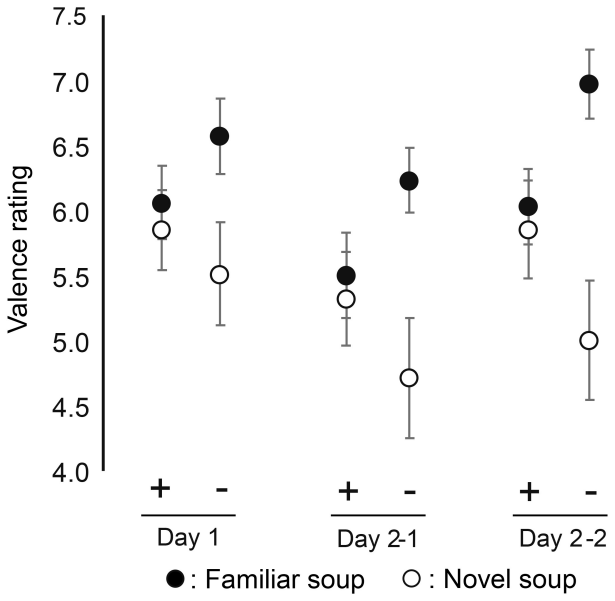

FIGURE 3 | Mean valence ratings of familiar and novel soup by positive emotional group (+) and negative emotional group (–) in Day 1, Day 2–1, and Day 2–2. Error bars indicate standard error of the mean.

for negative compared to positive emotional state. Note that only *happy*, *pleasant*, and *good* pass the Bonferroni-corrected α level of $p = 0.002$. As for valence, *post-hoc* comparisons indicate that there was no significant difference between the soups in the positive emotional state, but that in the negative emotional state, familiar soup was more positively judged than the novel soup. The negative emotions, *disgusted* and *guilty*, which showed a significant interaction between soup and state, revealed a consistent pattern with stronger-rated negative emotions for the novel soup than the familiar soup, for negative compared to positive emotional state [*disgusted*, $F(1, 345) = 7.56$, $p = 0.006$, $\eta_p^2 = 0.031$; *guilty*, $F(1, 345) = 5.82$, $p = 0.016$, $\eta_p^2 = 0.027$]. Finally, *bored* showed a significant soup × state interaction [$F(1, 345) = 4.54$, $p = 0.034$, $\eta_p^2 = 0.043$], indicating that participants with a positive emotional state rated the novel soup as less boring than the familiar soup for the positive rather than the negative emotional state, fitting with the other EsSense25 and valence results. However, none of the effects found for negative emotions pass the Bonferroni-corrected α level. For none of the emotions was a significant three-way interaction found, indicating that the interaction effects between soup and emotional state are stable across sessions (Hypotheses 3 and 4).

Behavioral Measures: Sip Size and Willingness-to-Take Home

Figure 5 shows the mean sip size for each soup, each of the two sessions that included sip size (Day1 and Day2–2, not Day 2–1), and each emotional state. **Figure 6** shows the mean number of cups of soup participants would want to take home (willingness-to-take-home) averaged across participants for each of the three sessions and of two emotional states. These behavioral measures showed a similar pattern of effects as the subjective ratings. There was no main effect of emotional state on sip size [$F(1, 66) = 0.26$, $p = 0.613$, $\eta_p^2 = 0.004$] and willingness-to-take-home [$F(1, 69) = 0.35$, $p = 0.557$, $\eta_p^2 = 0.005$], but significant interactions between emotional state and soups on both sip size [$F(1, 198) = 7.59$, $p = 0.006$, $\eta_p^2 = 0.126$] and willingness-to-take-home [$F(1, 345) = 11.16$, $p = 0.001$, $\eta_p^2 = 0.036$]. Similar to valence and EsSense25 ratings, sip size and willingness-to-take-home were lower for novel soup than for familiar soup in the negative emotional state, while there was no difference between soups in the positive emotional state. This was corroborated by *post-hoc* comparisons. No significant three-way interactions were found for both measures, indicating a stable effect of emotion on familiarity across sessions. **Table 1** shows that also the main effect of soup and the lack of effect of state × session that were observed for valence ratings, and most of the Essense25 ratings are mirrored in the patterns of sip size and willingness-to-take-home (Hypothesis 5).

DISCUSSION

The present study investigated the effect of emotional state (positive and negative) on valence and EsSense25 ratings, reported willingness-to-take-home, and sip size for novel and familiar soups, both at the time of emotion induction (Day 1) as well as at two recording sessions a week after (Day 2–1, without tasting, and Day 2–2, with tasting).

At Day 1, participants tasted and rated the soups for the first time, after an either positive or negative emotion induction procedure. For Day 1, we expected that overall experienced food pleasantness, as reflected in the valence ratings and the EsSense25, would be lower when tasting soups in a negative

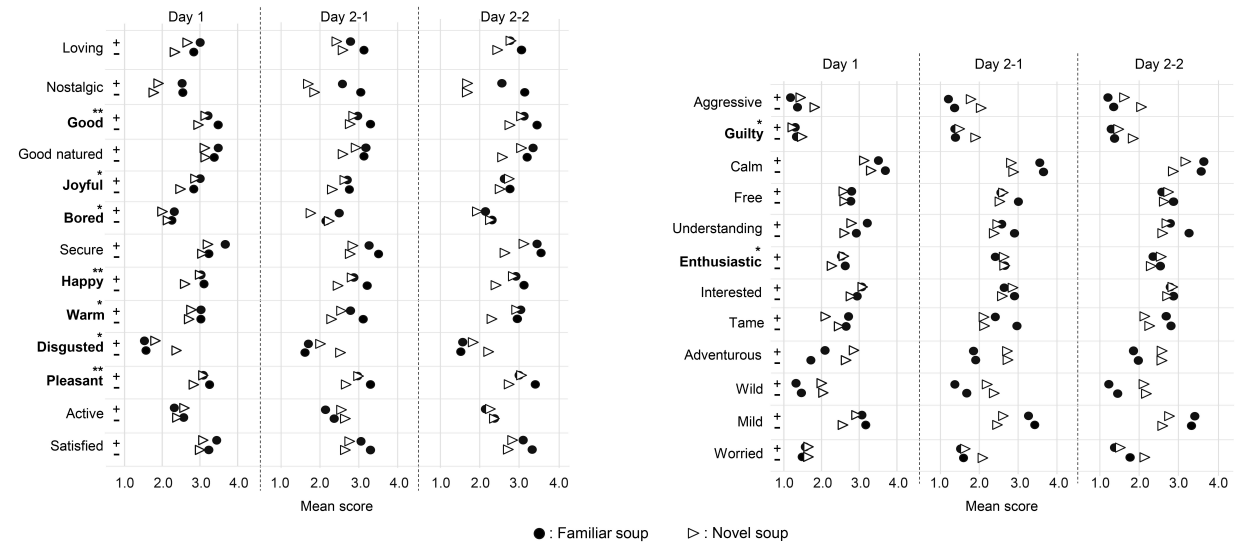

FIGURE 4 | Mean rated scores of each emotion based on EsSense25 of familiar and novel soup by positive emotional group (+) and negative emotional group (–) in Day 1, Day 2–1, and Day 2–2. Bolded emotions indicate significant interactions between emotional states and soups with $^{*}p < 0.05$ and with **Bonferroni correction of $p < 0.002$.

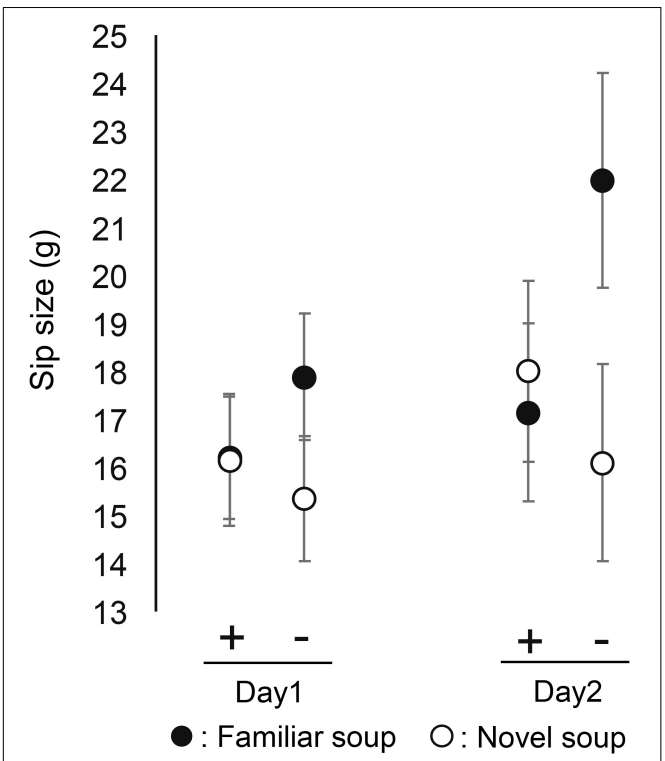

FIGURE 5 | Mean sip size of familiar and novel soup by positive emotional group (+) and negative emotional group (–) in Day 1 and Day 2–2. Error bars indicate standard error of the mean.

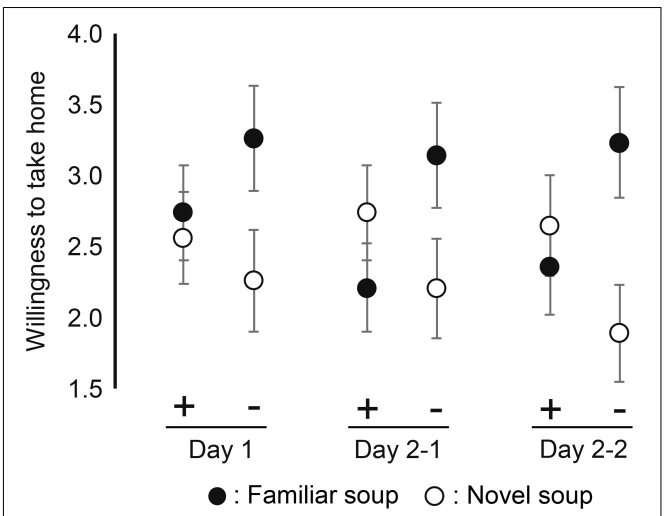

FIGURE 6 | Mean willingness-to-take-home of familiar and novel soup by positive emotional group (+) and negative emotional group (–) in Day 1, Day 2–1, and Day 2–2. Error bars indicate standard error of the mean.

emotional state than in a positive emotional state and that this effect would be stronger for the novel soup than for the familiar soup. We indeed observed that participants with a negative emotional state rated lower valence for the novel soup than for the familiar soup, whereas there was no difference between soups in the positive condition. However, the lack of a main effect of emotional state indicated that this was not merely due to a general lower valence in the negative condition. Rather, familiar soup was rated more positively in the negative emotional condition than in the positive emotional condition. For EsSense25, this pattern was found for three positive emotions (*happy*, *pleasant*, and *good*) and an additional three when a more liberal criterion of significance was taken (*warm*, *joyful*, and *enthusiastic*) and three negative emotional terms (only without Bonferoni correction: *bored*,

disgusted, and *guilty*). These results force us to reject Hypothesis 1—we did not find that negative emotional state decreased experienced food pleasantness in general, but partly supported Hypothesis 2—we found that negative emotional state decreased food pleasantness particularly for novel foods, where familiar food, contrary to our expectation, rather increased in food pleasantness. Our results are consistent with a comforting effect of a familiar taste in a stressful situation.

In the negative emotional group, we found that familiar soup was preferred over novel soup. In general, familiar foods are reported to be preferred over unfamiliar food. Fenko et al. (2015) investigated participants' hedonic responses to various familiar and unfamiliar soy product images and found higher liking scores for familiar products, as well as a more positive expectation of the familiar products' taste. Consistent with this, Toet et al. (2019) found that Asian and Western participants rated food from their own culture as more positive. Our study shows that this tendency may be especially strong in stressful situations. This is also suggested by a study from Locher et al. (2005). They asked participants to bring foods that "made them feel good" or "provided them comfort" and to explain why this was so. They concluded that people consume familiar foods to relieve feelings of distress and anxiety and that novel foods cannot fulfill this need because they tend to evoke more feelings of anxiety. Other studies report that individuals in depressed moods show a preference for and consume palatable well-known "comfort foods" to alleviate their negative feelings (Macht, 2008; Singh, 2014). Also, it is reported in a review that familiar foods represent the sense of perceived "comfort," while it is absent with novel foods because of a lack of knowledge of them (Aldridge et al., 2009).

We hypothesized that the differential effects of emotional state on novel and familiar soups would be stronger a week later when the actual taste of the soup is not available (Hypothesis 3). This pattern could be observed in most measures. For valence ratings, the difference between familiar and novel soup in Day 2–1 tended to be larger for participants that had been under negative stress than for participants from the positive emotional condition. The EsSense25 measures showed similar effects for certain positive emotions, such as "*good*," "*joyful*," "*happy*," "*warm*," "*pleasant*," and "*enthusiastic*," as well as sip size. However, significant three-way interactions between soup, state, and session were far from significant for any of the measures. Thus, we conclude that the differential effect of emotion on experiencing familiar and novel soup on Day 1, when the emotions were induced, remained the same a week later, therewith rejecting Hypothesis 3.

We expected that when participants would taste the soups again (Day2–2), this would reduce the effects of memory (Hypothesis 4). However, the lack of three-way interactions between soup, state, and session showed this not to be the case—even after tasting the soups again, the interactive effect of soup and emotional state remained the same for all measures. Hypothesis 4 was therefore rejected. Our data showed that the interactive effect of emotional state and familiarity (soup) is robust. For ratings, this may have been caused by participants being inclined to give similar answers as they did before. De Wijk et al. (2019) pointed out that memories of previous encounters with the same test food may induce the use of similar ratings in new encounters. However, the finding that our implicit measure of sip size produced the same results argues against this explanation in our study.

We used different measures to evaluate food experience from various angles. Valence rating, sip size, and willingness-to-take-home showed similar patterns of effects of soup, state, and session. This pattern was also seen in emotions probed in the EsSense25. Our Hypothesis 5 was thus confirmed.

Overall, we found that the results related to participants' food evaluations (valence, EsSense25, willingness-to-take-home, and sip size) did not completely follow our hypotheses. In fact, no main effects were observed of emotional state, although we did find significant interactions between emotional state and food novelty in all measures. The results showed that in the negative emotional condition, familiar foods were rated more positively than novel foods, whereas they were rated the same in a positive emotional state. We had expected perception of familiar foods to be more stable than novel foods across emotional conditions because of a long-term emotional association in memory in the participants. The fact that a food is familiar can be taken to mean that it is "safe," and thus in general more positive than novel foods. In the negative, stressed condition, individuals may have been more sensitive to any potential threats, resulting in an increased avoidance (or negative valence). On the other hand, when in a positive state, there is no reason to activate the threat awareness or avoidance mechanism, and individuals do not avoid food just because it is unfamiliar. The ratings in the positive emotional group may be mainly based on the smell and taste and not so much affected by the fact that they have not experienced it before. For future studies, it would be of interest to investigate if and how food neophobia affects these interactions between emotional state and food novelty on experienced food pleasantness.

The results in this study implicate that one should introduce a new product (or a novel food) in a situation where people are not stressed. Introducing a new product to consumers who are likely to be stressed (e.g., in a hospital) would not be recommended as it may affect food pleasantness negatively and for a long period. Once people have experienced a new product in a stressed state, the negative effect is robust at least for 1 week. Therefore, a positive recommendation would be to let people taste a new product when they are in a positive mood, e.g., at a festival or after a happy movie.

CONCLUSION

This study evaluated the interaction effects between emotional states and food novelty on food experiences in terms of valence and EsSense25 ratings, willingness-to-take-home, and sip size, both during initial tasting of two soups and a week later. We showed that the emotional state affected all these measures in a similar way, with low experienced pleasantness for novel food and high pleasantness for familiar food in the negative compared

to the positive emotional group, in which no differences in pleasantness were found. Also, the effects of emotional state proved to be robust over time (1 week later in this study). Our findings in this study provided relevant insights for food industries and restaurants for introducing their new products to consumers and for hospitals and care institutions for providing medication or food supplements.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the TNO Institutional Review Board (TCPE). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DK, A-MB, VK, and JE: conceptualization. DK and MH: data curation and software. DK, A-MB, MH, and JE: formal analysis. DK: funding acquisition, resources, and writing—original draft. DK, A-MB, MH, AT, VK, and JE: investigation. DK and A-MB: methodology, project administration, validation, and visualization. A-MB, AT, VK, and JE: supervision and writing—review and editing. All authors contributed to the article and approved the submitted version.

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The Consumer Contextual Decision-Making Model

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Consumers can have difficulty expressing their buying intentions on an explicit level. The most common explanation for this intention-action gap is that consumers have many cognitive biases that interfere with rational decision-making. The current resource-rational approach to understanding human cognition, however, suggests that brain environment interactions lead consumers to minimize the expenditure of cognitive energy according to the principle of Occam's Razor. This means that the consumer seeks as simple of a solution as possible for a problem requiring decision-making. In addition, this resource-rational approach to decision-making emphasizes the role of inductive inference and Bayesian reasoning. Together, the principle of Occam's Razor, inductive inference, and Bayesian reasoning illuminate the dynamic human-environment relationship. This paper analyzes these concepts from a contextual perspective and introduces the Consumer Contextual Decision-Making Model (CCDMM). Based on the CCDMM, two hypothetical strategies of consumer decision-making will be presented. First, the SIMilarity-Strategy (SIMS) is one in which most of a consumer's decisions in a real-life context are based on prior beliefs about the role of a commodities specific to real-life situation being encountered. Because beliefs are based on previous experiences, consumers are already aware of the most likely consequences of their actions. At the same time, they do not waste time on developing contingencies for what, based on previous experience, is unlikely to happen. Second, the What-is-Out-there-in-the-World-Strategy (WOWS) is one in which prior beliefs do not work in a real-life situation, requiring consumers to update their beliefs. The principle argument being made is that most experimental consumer research describes decision-making based on the WOWS, when participants cannot apply their previous knowledge and situation-based strategy to problems. The article analyzes sensory and cognitive biases described by behavioral economists from a CCDMM perspective, followed by a description and explanation of the typical intention-action gap based on the model. Prior to a section dedicated to discussion, the neuroeconomic approach will be described along with the valuation network of the brain, which has evolved to solve problems that the human has previously encountered in an information-rich environment. The principles of brain function will also be compared to CCDMM. Finally, different approaches and the future direction of consumer research from a contextual point of view will be presented.

Keywords: inductive inference, Occam's razor, Bayesian reasoning, consumer, decision-making, neuroeconomics

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INTRODUCTION

The sheer number of consumption opportunities on the market outweighs consumers' ability to assess them. This limitation to human mental capacity is a problem for most decision-making models. First, traditional models for consumer decision-making (Samuelson, 1938; Luce and Raiffa, 1989; Barry and Howard, 1990) assume that people are driven by explicit reasoning across all options. These models simply conceptualize consumer decisions as a matter of choosing the best option from those available (Kőszegi, 2010). Furthermore, these models assume that people respond only to the features of the options available to them independent of context and unaffected by other available alternatives or temporal order. These models also assume that consumers' preferences are invariant and that they follow principles of transitivity and other axioms presented on rational choice theory (Samuelson, 1938; Luce and Raiffa, 1989). Despite the use of sophisticated axiomatic and formal framework (Luce and Raiffa, 1989), these traditional models have limited capacities to decode the intentions and thoughts driving consumer behavior in the real market. The observed behavior of consumers is much more complex than these traditional models assume (Dijksterhuis et al., 2006).

Second, behavioral economic models have shown that consumers often violate the basic axioms of traditional models (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991). According to behavioral economic models, human decision-making behavior is systematically biased (Tversky and Kahneman, 1991; Shafir and LeBoeuf, 2002; Bottom et al., 2004) and "predictably irrational" (Ariely, 2009). Behavioral economics therefore has a low opinion of human rationality (Palokangas and Suomala, 2017).

Both the traditional and behavioral economic models assume that the aim of consumer decision-making is the recovery of real-world options – that is, objective consideration of sets of commodities. They assume that a consumer enters the market environment as a *tabula rasa,* and that the representation process only begins after an objective marketing stimulus or sets of marketing stimuli are presented. Then the task of the consumer's mental system is to generate a representation of the exact properties and attributes of commodities in the market environment. Personal goals, previous consumption history, and contextual factors have been regarded either as irrelevant (by traditional models) or as sources of cognitive bias (by behavioral economic models).

These models have several problems. First, they are insufficient to identify consumers' prior beliefs about different market contexts. This is particularly evident in the fact that most new products fail in the market. Second, they suffer from a lack of ecological validity because their basic arguments are based solely on mathematical axioms (Luce and Raiffa, 1989) and strict experimental settings (Kahneman and Tversky, 1979). The argument is not that mathematical axioms and experimental settings are the problems *per se*. Advocates of traditional models have proofed consumer decision-making in sophisticated ways, but the explanation power of these models is frustratingly limited. The problem is more that these models explain consumer decision-making in a way that is not really what decision-making in the real market looks like. Therefore, the goal of this article is to build a more plausible framework for the description and explanation of consumer behavior in real market contexts.

According to more recent contextual models of human decision-making, the brain infers based on prior experience and expectation, not only of observable goods but also of the latent causes of these goods and whole context (Baum, 2004; Gershman and Niv, 2013; Büchel et al., 2014). When real market contexts include more information than the consumer can process, the brain needs to apply an effective strategy to concentrate only on meaningful information. In order to build a more plausible model of consumer decision-making, recent work has sought to identify shared principles in the mechanisms underlying subjective valuation and sensory perception (Louie and Glimcher, 2012; Woodford, 2012; Polanía et al., 2019). These contextual models have suggested that mental representation resembles sensory perception in that they are both made up of inference processes that exploit information on the relevant properties and occurrences of commodities in the environment (Polanía et al., 2019). In short, the role of the mental system of a consumer in a decision-making situation is not to represent the physical world, but to promote useful behaviors. It is essential to note, however, that a context is simply a platform on which the valuation of commodities and decision-making pertinent to coping with life are tested (see Purves et al., 2015). Decision-making reflects subjective meaningfulness based on experience rather than objective features of the environment. The goal of this article is to clarify this idea on a conceptual level. To this end, the Consumer's Contextual Decision-Making Model (CCDMM) is presented on a conceptual level in section The Consumer's Contextual Decision-Making Model (**Figure 1**). The model was constructed based on contextual and resource-rational models of human behavior and decision-making (Griffiths et al., 2015; Tymula and Plassmann, 2016; McKenzie et al., 2018).

The remainder of this paper is organized as follows: section Consumers Control Contexts by Expectations seeks to explain consumer decision-making from a contextual perspective. Before presenting the CCDMM itself, three basic theoretical constructs will be presented. First, inductive reasoning is humans' unique capacity for extracting meaningful mental representations from sparse data. Second, the principle of Occam's Razor will be introduced. This principle states that people prefer a simple explanation of the world over a complex one. The third basic principle behind the CCDMM is Bayesian reasoning. According to this principle, people have an existing internal model of the environment based on actions previously carried out in that environment. These existing beliefs help consumers to anticipate and interpret the structure and functions of the market. Subsequently, typical sensory illusions are presented as an example of the human capacity to mentally adapt to different contexts. Finally, the CCDMM itself (**Figure 1**) is presented. Section SIMS, WOWS, and Contextual Rationality begins with an exploration of two main decision-making strategies, the SIMilarity-Strategy (SIMS) and the What-is-Out-there–in-the-World-Strategy (WOWS). Both are justified by the CCDMM. A new interpretation of the concept of human rationality is then introduced and justified. Section CCDMM

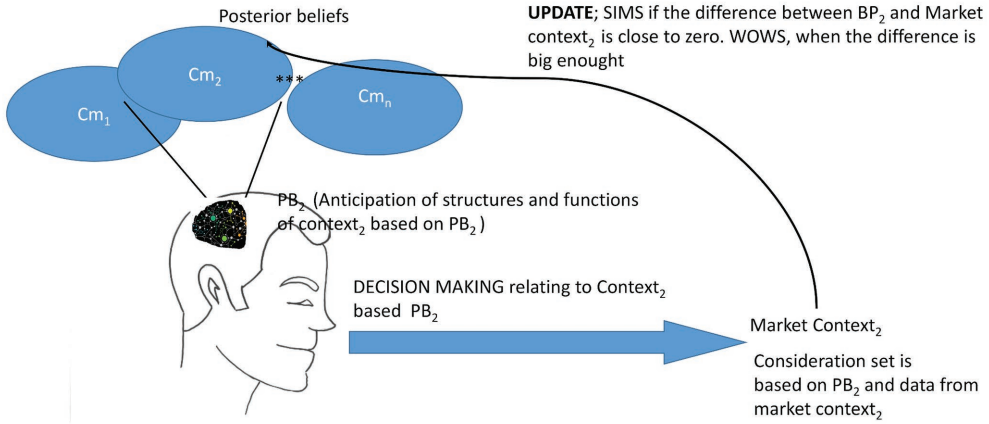

FIGURE 1 | Consumer's Contextual Decision-Making Model (CCDMM). A consumer makes decisions in the market based on his mental models of different contexts. Cm_1, Cm_2 …. Cm_n mean a contextual $model_1$, a contextual $model_2$, and a contextual $model_n$. Let us assume that the consumer remembers that his daughter's birthday is coming soon. This memory activates the contextual model for "my daughter's birthday party," and this is described as Cm_2, which again activates prior beliefs PB_2 and the mental construct of anticipations about a child's birthday party. The PB_2 activates the consumer to run an errand, in this case a visit to a department store. There, the consumer purchases gift/gifts and other supplies for the daughter's birthday. If the PB_2 corresponds to the anticipation of commodities (consideration set relating to the daughter's birthday party), the update process leads to the posterior belief, which is the same as prior belief. In this case, the consumer applies SIMilarity Strategy (SIMS). However, if something in the department store is better or more interesting than PB_2 based expectations, posterior belief will be updated, and will be different from prior beliefs. For example, if some new ice cream product for a children's birthday party is available, the person might begin to think that it is good idea to also provide ice cream at the birthday party. When there is big enough difference between expectations and data in the market, the consumer uses the What-is-Out-there-in-the-World Strategy (WOWS), and updates his prior beliefs relating to the daughter's birthday party. Of course, updating can go also in the negative direction.

and Neuroeconomics discusses the most common intention-action gaps based on this new interpretation. In the same vein, framing and decoy effects will also be presented. Following this, the most typical neuroeconomics research is reviewed from the CCDMM perspective, and why the brain's valuation network produces rational and adaptive signals to help individuals to cope in a wide variety of contexts is also explained based on the CCDMM. The article culminates in a brief discussion.

CONSUMERS CONTROL CONTEXTS BY EXPECTATIONS

The world around a consumer is complex and noisy, and it includes many uncertainties. Imagine an everyday situation in which a consumer goes to a department store. A typical department store has over 100,000 products. Whereas offers in this real market context represent more information than the consumer can access, the brain needs to apply an effective strategy to concentrate on the most essential information. This strategy is illustrated by the CCDMM, for which inductive inference, the principle of Occam's Razor, and Bayesian inference are the three building blocks.

The Three Building Blocks of Consumer Decision-Making

Inductive Inference

One of the greatest enigmas of human behavior is how experience leads to the formation of general and abstract knowledge. Inductive inference refers to people's ability to infer a general principle based on observation of particular instances. Inductive inferences go beyond available data in order to arrive at plausible conclusions given what is available (Noonan, 2007; Quine, 2013). Humans are predisposed to divide the world up into objects, to understand the interactions that occur between these objects, and to apply a variety of attitudes and values to the representation of these objects. Inductive inference helps people to identify the most meaningful things about their environments (Baum, 2004). If consumers are indifferent about which goods are better than others, they will have no way of choosing the "better" good, nor will they have any way to learn (Baum, 2004).

While the origins of inductive inference are still a matter of debate, it is clear that this ability is emerges early during a person's development and plays an important role in learning, thought, and decision-making. Thus, inductive inference is essential to the human capacity for deriving general knowledge about the structure and function of different environments from sparse data. Consider that just a few examples are enough for children to learn the meaning of certain words (Gärdenfors, 2014), causal reasoning (Gopnik and Sobel, 2000), property induction (Madole and Cohen, 1995), and social cognition (Tomasello, 1995; Gärdenfors, 2014; Lake et al., 2017).

One of the most important features of inductive reasoning is that people can learn even faster if they combine their own experience with just a little help from others (Lake et al., 2017). In social contexts, people do not only learn solely based on observations of what other people do, but also of what they do not do. As such, consumer behavior can depend on unchosen latent alternatives (Gershman et al., 2010; Kőszegi, 2010). This negative evidence and latent reasoning teach people how to avoid – without direct experience – indifferent or negative aspects

of different contexts. This kind of latent reasoning as part of inductive inference without direct personal experience is almost completely missing from traditional and behavioral economic models alike. This review of inductive reasoning leads to the conclusion that the concept of meaningfulness is the strongest trigger of consumer choice, though the content of meaningfulness is different among individuals from different cultural contexts.

The Principle of Occam's Razor

The fourteenth-century English theologian William of Occam's famous advice to scientists was "not to multiply entities beyond necessity" (William and Brown, 1990). This principle, that an explanation of facts should be no more complicated than necessary, is widely accepted in the fields of science (Jaynes, 2003) and algorithmic information theory (Li and Vitányi, 2008). Though the principle is not commonly used to describe and explain human behavior, it has been recently applied to cognitive science (Gershman and Niv, 2013; Griffiths et al., 2015) and studies in preference-based decisions (Polanía et al., 2019). In addition, studies of sensory systems (Heeger et al., 1996; Barlow, 2012) and the brain valuation network (Tymula and Glimcher, 2016; Steverson et al., 2019) epitomize the original concept of Occam's Razor.

Furthermore, the principle is central to human thought processes themselves. By analogy, just as science seeks a simple explanation for as many observations as possible, so do humans in their thought processes; people are like scientists seeking a simple explanation of the world, which, once found, is embodied in the mind (Baum, 2004). Baum (2004) takes this idea even further and argues that evolution has identified and saved simple rules into humans' DNA, and that these rules work well in many contexts. From this perspective, our understanding of the world is a very compressed representation of it.

In addition, Occam's principle has been used to explain category learning (Sanborn et al., 2010; Gershman and Niv, 2013). Evidence from category learning suggests that humans assign stimuli to a small set of categories, only inventing new ones when stimulus statistics change radically. For example, Gershman and Niv (2013) had participants estimate the number of colored circles on a computer screen, with the number of circles drawn from a color-specific distribution. When the color-specific distributions overlapped substantially, participants' estimates were biased toward values intermediate between the two means, indicating that subjects grouped different-colored stimuli into one perceptual category. The study showed that humans favor simpler explanations of sensory inputs.

Consumers exhibit clear behavior when they decide which goods or services are suitable to their needs and interests. The principle of Occam's Razor can therefore be extended to consumer behavior, as we may hypothesize that the simplest choice to accomplish a consumer's subjective goal is the best one. Occam's principle also has deep connections with Bayesian reasoning (Baum, 2004), which is the focus of the following section.

Bayesian Reasoning

The idea, that uncertain state of the world can be modeled by a prior belief with observed data, is created by Protestant theologian and minister Thomas Bayes. He lived on the eighteenth-century in England and is today such a famous name for in mathematics and statistics. This article explains consumer decision-making by applying Bayesian approach on conceptual level. Human behavior relies heavily on anticipating future states according to meaningfulness in an uncertain environment and on maintaining appropriate actions to achieve personally meaningful goals. In a real market context, the degree of uncertainty about possible outcomes will escalate drastically as the number of products and services available to a consumer increases. If examined from the perspective of the Bayesian approach, however, the consumer has recourse to an existing internal model of the environment, which can be used to anticipate and interpret its structure and function. This internal model includes both innate and adaptive components. However, it is difficult to separate these components entirely, because the innate components are also highly adaptive and the adaptive component includes mechanisms that are innate (Wilson et al., 2018). When encountering a new context, then, the consumer may infer the degree to which the information in a situation corresponds to his or her anticipation. According to Bayesian terminology, a consumer "counts" the likelihood (i.e., the probability) of the data given a hypothesis. If the information (data) of the situation does not correspond to the consumer's anticipation (hypothesis), mental disequilibrium arises and the individual must update his or her internal model. Subsequently, this update leads to a posterior model of the context (Jaynes, 2003; Baum, 2004; Kording, 2014). Within Bayesian statistics, a previously acquired mental model is called the *prior*, while the discrepancy between new information and the prior is called the *likelihood*. According to the Bayesian approach, humans have an internal model of given contexts, which helps them to navigate different situations.

To reiterate, according to the Bayesian approach, people use prior knowledge to calculate the probability of a related event. The Bayesian approach has become increasingly important both as a tool in many areas of science (Jaynes, 2003; Lake et al., 2017) as well as a model for human learning and behavior (Friston et al., 2006; Kemp and Tenenbaum, 2008; Dasgupta et al., 2018). However, its application to consumer decision-making is less common. The Bayesian approach is a realistic and dynamic tool for understanding human behavior and learning mechanisms in the context of consumer behavior. When consumers encounter new or unexpected information, they are required to actively reformat it based on prior beliefs and new data to better serve their personal goals. When consumers receive even more data, posterior beliefs become new priors. This cycle continues indefinitely as people are continuously updating their beliefs, which is valuable to understanding decision-making. The Bayesian approach assumes that the mind inverts the internal model to compute expectations about the state of the environment. It is important to emphasize that the state of the environment includes objects, their interactions, and their latent and perceptual causes (Gershman et al., 2010; DuBrow et al., 2017).

The Bayesian approach includes one important aspect about reasoning during decision-making. The accuracy of human

judgment does not only depend on how accurately an individual manipulates information in an environment, but also on how well the information corresponds to prior experience and knowledge. This prior experience gives rise to a form of expectation based on prior belief, in which people are more accurate when asked to make decisions about "believable" problems than about "unbelievable" problems, even when the logical form of these problems is equal. This is an important point, because traditional and behavioral economic models are almost silent about the prior beliefs of a consumer, and assume that the consumer logically reasons, in the classical deductive inference sense, in a market context. However, a consumer tries to make sense of the context based on prior beliefs and expectations about meaningfulness.

Despite the fact that many studies have found that people's judgments and decisions are very closely aligned with Bayes' optimal prediction (Griffiths and Tenenbaum, 2006), people also violate these norms (Dasgupta et al., 2018). The reason for this violation might be the curse of dimensionality: the more information and dimensions an environment has, the more combinations of features or states consumers have to learn. This makes consumers decision-making prohibitively "expensive" in terms of the amount of experience needed to master all information in a specific context.

Economics and the free market economy have long assumed that the more options there are, the better. However, this traditional view runs counter to empirical evidence that consumers make worse decisions and are more disappointed with their decision when the number of choice sets increase (Iyengar and Lepper, 2000; Iyengar and Kamenica, 2010).

Thus, consumers make approximations about the most essential features of the environment and then compare the data to their mental model according to the Bayesian principle. At least in part, the Bayesian approach solves the curse of dimensionality (Dasgupta et al., 2020) if it is assumed that inductive inference addresses and learns the most important aspects of the individuals' environment. In this sense, cultural habits, social norms, and attitudes play an important role in consumer decision-making.

Inductive inference, Occam's Razor, and Bayesian learning illuminate the dynamics of the human-environment relationship and are the three building blocks of the CCDMM. Respectively, they indicate that the concept of meaningfulness is the strongest trigger of consumer choice, that the best means of accomplishing this choice or goal is the simplest one, and that cultural habits, social norms, and attitudes play an important role in consumer decision-making.

Sensory Perception as an Illustration of the Sophisticated Human Mental System

The study of how properties of context is represented in the brain mainly begins with the study of sensory systems. These studies have shown that the activity of neurons in the sensory areas of the brain is conditional on the expectation of future properties of stimuli cortices (Tymula and Glimcher, 2016; Heeger, 2017). Recently, neuroeconomics studies have found that the human brain – especially its valuation network – is dynamically adjusted in response to expectations (Woodford, 2012). The physiological responses of sensory neurons show outcome expectations that match the manner in which models of decision-making predict expectations according to utility functions (Woodford, 2012; Tymula and Glimcher, 2016). Therefore, extensive evidence of these studies of sensory perception have identified the fundamental primitives of many common neurophysiological functions and representations, which are sensitive for predictions not only in the sensory areas, but also in the valuation areas in the brain, which drives the human decision-making process (Tymula and Glimcher, 2016).

At the heart of the CCDMM lies the idea that we do not interpret our world merely by analyzing incoming sensory information, but rather we try to understand it by proactively linking incoming sensory information to familiar prior beliefs (Bar, 2011). In this way, our perception of the environment relies on prior beliefs as much as it does on incoming information, which blurs the border between sensory information and decision-making (Bar, 2011). The three examples of perceptual illusions describe how our brains make approximations in order to behave in suitable ways in different contexts.

Perceptual illusions are well-known phenomena in psychology (Glimcher, 2011), and scientists have applied the findings of perceptual illusions, when they have built conceptual foundations for context-dependent decision-making models (Glimcher, 2014). Whereas behavioral economists view these illusions as an indication of the human tendency toward irrational behavior (Thaler and Sunstein, 2009), recent contextual approaches have emphasized, rather, that these illusions expose the effectiveness of the human mental system (Glimcher, 2011; Tymula and Plassmann, 2016; DuBrow et al., 2017; McKenzie et al., 2018). The core lesson from studies of perception is that sensory encoding is context-dependent, and that objective representations of context are not possible.

Moving from a windowless office to a sunny outdoor terrace, for example, epitomizes the visual system's adaptiveness to context. Sitting in an office, we see a colleague wearing a blue jeans and a green shirt. The light reflected from the blue jeans gives rise to perceptual experience based on approximately 10^{17} photons/s with a mean wavelength of 450 nm streaming off every square centimeter. In a similar way, about 10^{17} 550-nm photons/s/cm^2 are streaming off of the green shirt. Next, we step outside into the bright sun with that colleague for lunch. On the outdoor terrace, he looks the same: blue jeans and a green shirt. However, in bright sun, this identical perceptual experience is being produced by around 10^{23} 450-nm photons/s/cm^2 streaming off of the blue jeans and approximately 10^{23} 550-nm photons/s/cm^2 streaming off of the green shirt. As Paul Glimcher (2011, p. 275) describes, "on a typical day this is a *six-order-of-magnitude* shift in the objective reality, which has been accompanied by no significant change in the subjective experience." In other words, despite such a significant change in objective reality, we experience our observations the same. The reason for this stable experience should be obvious from an evolutionary perspective. The most important things we need to understand in order to survive are the objects and people

in our immediate surroundings, not the sun located 150 million kilometers away. To extract the properties of our immediate context accurately, our senses have to subtract the changing effects of the sun as we move under clouds, into shadow, or into direct sunlight. This adaptation economizes the brain's energy consumption and helps us to navigate effectively in different environments.

As another example, the Adelson's Checker-Shadow Illusion presents two simultaneously perceived targets as identical local stimuli – that is, they are reflecting identical numbers of photons to the human eye. However, one is perceived as being lighter than the other (Glimcher, 2011). Again, a human will perceive the tiles as being different due to a spatial reference dependence triggered in the visual system by the differently shaded tiles that surround them (Glimcher, 2011). Similarly, in the table Illusion of Shepard (1990), people perceive one table to be longer and thinner than the other, even though they are the same size on the page.

In addition, other sensory encodings are reference-dependent, and nowhere in the nervous system are there objective representations of surrounding context. Because people receive much more sensory information than they can physically process, the sensory system's central purpose is to help people navigate the 3D world. Then a sensory system can only make a "best guess" about the configuration of objects in the 3D world (Helmholtz, 1873; McKenzie et al., 2018). A sensory system draws on contextual cues within this system to construct this guess. Whereas behavioral economics (Thaler and Sunstein, 2009) use sensory illusions as examples of people's shortcomings of our cognitive system, McKenzie et al. (2018) argue that illusions showcase the sophistication and adaptiveness of the human mind. Sensory processes help us to understand how the system gets things right, not wrong, in the real (3D) world.

If a consumer does not follow the rules of traditional economic models, what are the rules behind consumer behavior? According to a contextual approach, optical illusions and other behavioral biases are manifestations of the human ability to adapt *effectively* to the environment. These adaptive skills need not be exact copies of the world; approximations are enough. There is good reason from an evolutionary psychological perspective, for a human's mental processes to optimize an inflow of information by making approximations, rather than objective copies of the environment. Unexpectedly, many patients with neurophysiological deficits perform better in perceptual illusion tasks than healthy participants. For example, Fine et al. (2003) describe a sight-recovery patient ("MM") who perceived Shepard's Tables to be the same size. MM was blinded at age 3 and like other sight-recovery patients, had difficulty with 3D interpretation of retinal images. Similar deficits in approximation during different visual perception tasks have been observed in schizophrenia patients (Dakin et al., 2005), patients with memory deficits (Edin et al., 2009), and among autistics (Heeger, 2017). The fact that different kinds of patients do not fall prey to visual illusions is indicative of an impaired visual or other mental system, rather than an ideal one (Heeger, 2017; McKenzie et al., 2018).

Consistent with arguments made by McKenzie et al. (2018), this article argues that interpretations of consumer's decision-making as being irrational are sometimes misguided in ways that are analogous to the interpretation of visual and other sensory illusions as being indicative of a shortcoming of the visual and other sensory systems. What appear to be violations of original choice theory turn out to reflect adaptive responses to relevant information in a decision-making context.

Traditional models of consumer choice assume that an ideal consumer chooses based on his or her explicit, fixed beliefs and preferences. However, it is well-known that although human representations are routinely at odds with physical measurements of real world properties (Purves et al., 2015), these representations lead to effective behaviors and decisions (McKenzie et al., 2018). According to a contextual approach, the task of human representation is not to recover properties of the world in a traditional, logical sense, but rather to cope with different situations by promoting useful behaviors in life. Then consumers' representation of information reflects biological, social, and cultural experiences as well as the most important patterns of the current environment rather than objective features of the environment in an objective sense (Barkow et al., 1992; Purves et al., 2015; McKenzie et al., 2018; Martens, 2019).

The Consumer's Contextual Decision-Making Model

Despite the fact that traditional economic models have excluded context when explaining consumer behavior, there are many psychological and neuroeconomics studies that have shown that consumer behavior is strongly context-dependent (Louie and De Martino, 2014). Axiomatic contextual approaches have also been developed within traditional economics that view consumers' willingness to pay for a good not as fixed, but rather dependent on the market environment and how they respond to it (Kőszegi, 2010). The meaning of "context" in this sense varies from a single stimulus and option sets to a social structure. Consumers are sensitive to the size of choice sets, the order of options, and the relationships between the different options within a choice set (Louie and De Martino, 2014).

In addition, psychologists have recognized that the representation of social choice sets affects which target features become most salient, and as a consequence, how each constituent individual or social group within the choice set is evaluated (Chang et al., 2019). Furthermore, mutual understanding is often structurally built into context. For example, trust is based on the shared belief that each person will behave accordingly in a specific context. Bacharach and Gambetta (2001) have termed the degree of trust in a given context as its "trust-warranting properties." In most situations, trust is formed based on considerations other than pay-offs. Many social properties, for example, increase trust, such as commonly-held values, perceived honesty, benevolence, and cultural dispositions and practices (Keren, 2007). Thus, the concept of context includes physical and social functions, structures, and their interactions. According to the CCDMM, a consumer learns to predict these context-specific properties.

The CCDMM assumes that consumers do not act without considering the likely consequences of their actions. They do not

waste effort planning for future contingencies that are very unlikely to happen (Jaynes, 2003). Consumers anticipate properties in different contexts based on prior beliefs and experiences. The consumer uses these previous experiences, which we call "priors" in the Bayesian language, to processes information in a specific context. **Figure 1** presents the CCDMM.

The previous contextual approaches typically assume that consumers' decision-making begins based on stimuli – in this case any goods on the market, as shown in **Figure 1** (Gershman and Niv, 2013; Tymula and Plassmann, 2016; DuBrow et al., 2017). On the contrary, it is essential, according to the CCDMM, that the mental context (e.g., Cm_2 in **Figure 1**) is the starting point for the consumer's decision-making. Decision-making is based on either SIMS or WOWS.

A marketing context is formed of elements that have an internal structure. Elements that belong to the same context have a high frequency of spatial and temporal co-occurrence compared to the elements that do not belong to the same context (Schapiro et al., 2016; Tymula and Glimcher, 2016). Our contextual mental models (Cm1, Cm2…Cmn in **Figure 1**) organize and structure continuous experience. These context representations allow a consumer to apply his/her marketing knowledge (i.e., PB's in **Figure 1**) across time and space (Franklin et al., 2020).

The growing literature suggests that the hippocampus is especially important for the learning and extraction of internal structures in the environment (Schapiro et al., 2016). When an individual has a Cm_2 and begins to make decisions concerning a birthday party, he/she forms expectations about common elements concerning the birthday party. SIMS means that an individual's decision-making is based on a correspondence link between expectations and the real market context, and the value of this correspondence link is high. It is noteworthy, that the internal structure of a context does not only include only physical properties, but also their functions and symbolic meaning relate to this specific context. It is still an open question of how the brain forms this correspondence link between PB's and the market context. However, there is consensus that the traditional model based on a one-dimensional scalar function is not enough in order to describe and explain this complex process. Dayan (1993) introduces the concept of "the successor representation," which is a combination of the initial state and the destination state. From the perspective of CCDMM, the initial state is CM, the destination state is the marketing context and the correspondence link is the successor representation. Thus, a promising direction, in the vein of Dayan's model, will be to assume that both a PB and the real market context can be described by vector spaces and then the correspondence link between these two vector spaces can be counted computationally and experimentally in order to test CCDMM in a market-like context.

In line with the above argument, the WOWS means that an individual's decision-making cannot rely on the correspondence link between expectations and the real market context, because these two do not correspond strongly enough. What is a sufficient correspondence in order to apply SIMS or WOWS? That is a difficult question, because all information is novel to some degree and we never encounter anything twice in a strict sense (Bar, 2011). If we think that number 1 describes the total similarity between PB and the real market context and number 0 describes the complete difference between these, then there should be a specific equilibrium between PB and the market context for SIMS between 0 and 1. It is likely that this equilibrium – correspondence mapping between PB and the real market context – is closer to 1 in the case of SIMS. The argument here is that human behavior is driven according to the free energy principle, which means that our brains favor predictions, which are most probable in the market context (Seth, 2015). Therefore, the theoretical hypothesis here is that the equilibrium state should be biased to 1. When this equilibrium state begins to become unstable, an individual needs to apply WOWS and update the Cm relating to this context.

Although it is too early to determine what the exact equilibrium point (i.e., the value of the correspondence link) between the vector space of PB and the real market context is, when an individual needs to update Cm, and how much he/she needs to update it (a little evolutional change or a big revolutional change), there is some promising direction in the current studies relating to reinforcement learning (Takahashi et al., 2017; Franklin et al., 2020). These studies have shown that dopaminergic neurons in the brain are not only sensitive to value shift – when the context-related reward is better than expected – but also to the identity shift. These identity shifts are driven not only by the reward, but also by the content features of the context. Thus, there is neural correspondence between individual expectations and features of the context elements; this could be one neurophysiological trigger that upsets the equilibrium. In addition, the functional connectivity increases between the mPFC and hippocampus when participants in the experiment are in the transition phase between one context and the other (Schapiro et al., 2016). These findings of neurophysiological mechanisms when an individual changes his/her behavior relating to the changes in the context open new possibilities to determine the transition mechanisms of consumers, for instance, when they change their strategies from SIMS to WOWS. However, more behavioral and neurophysiological research is needed in order to prove this idea in a consumer decision-making context.

In a real market context, consumers use SIMS, because it is rational to assume that suitable commodities are available in a real market. In a real life problem requiring decision-making, most consumers have a reasonable idea of their prior beliefs, and because these beliefs are based on all of their past experiences, these prior beliefs experiences are not easily changed and are fairly stable (Jaynes, 2003). Most of a consumer's decision-making takes place in these kinds of regular and repeated contexts. However, when prior knowledge of context is minimal or limited, the best a consumer can do is construct an interpretation of the properties of the context and make a decision based on contextual information. In other words, the consumer applies WOWS in a new context. Whereas SIMS works in most real market contexts, most decision-making studies have been executed according to WOWS, in which participants cannot apply their prior beliefs.

SIMS, WOWS, AND CONTEXTUAL RATIONALITY

In real-life contexts, offers on the market include more information than the consumer can access, and the brain needs to apply an effective strategy to concentrate only on meaningful information. Whereas the concept of meaningfulness refers to the degree of significance an individual generally assigns to information, meaningfulness is still rooted in culture and in the values and attitudes it conveys. Then, the concept of meaningfulness has two components, the subjective goals and recognition (Ariely et al., 2008). The subjective goal refers to mental representations of potential future situations. These representations enable a person to produce control-related decision-making strategies (Geary, 2005). For example, when young people pursue the goal of graduating from university, they form subjective goals about their future earnings and these expectations have an important impact on their related decisions (Suomala et al., 2017). Recognition means that an individual's decision-making and behavior are socially and culturally acceptable and valued. Thus, the meaningfulness has two components: personal goals and recognition. According to this approach, the rational decision maker does not recover objective properties of the world, but copes with different situations by promoting meaningful behaviors in life. The decision maker's representation of information reflects the meaningfulness of the situation based on past experiences rather than objective features of the environment (Barkow et al., 1992; Geary, 2005; Purves et al., 2015; Martens, 2019).

Therefore, human behavior is biased to socially and culturally transmit values and attitudes. Thus, most consumers anticipate something "meaningful" to happen in specific contexts, and this leads to the SIMS.

However, when the typical anticipation for a specific context is disrupted, a consumer tries to understand the context based on available information. Thus, a consumer constructs a new model for the context by updating his or her prior beliefs based on contextual information and tries to find balance between uncertainty and prior beliefs using WOWS.

Three typical cognitive biases will be presented and interpreted based on the CCDMM. First, the example of *anchoring* illuminates how a consumer tries to balance prior beliefs and new contextual information. The anchoring effect is a cognitive bias that describes the common human tendency to rely too heavily on the first piece of contextual information offered (the "anchor") when making decisions (Tversky and Kahneman, 1974). Once an anchor is set, an individual will make subsequent decisions by interpreting information around the anchor. For example, the initial price offered for a house sets the standard for the rest of the negotiations, so that prices lower than the initial price seem more reasonable even if they are still higher than what the house is really worth.

In the classical experiments by Tversky and Kahneman (1974), participants were given an arbitrary number between 0 and 100 and asked to indicate whether the percentage of African nations in the United Nations was higher or lower than that number. Research participants then estimated the actual percentage. Results indicated that participants who had received a relatively high number as an anchor for comparative judgment gave higher absolute estimates than participants who were given a lower number as an anchor of comparison. If we accept that the anchor somehow infiltrated participants' prior beliefs, then it would have pulled estimates up or down because they did not possess any prior beliefs on the topic in this experiment. Therefore, it is a very relevant anchor. Thus, they applied WOWS in their attempts to understand contextual meaning. As another example, often rely on experts when it comes to a topic like scientific information being presented in media contexts, because they lack the relevant background information to make their own decisions (Bromme and Goldman, 2014). Thus, WOWS is a tool to cope with new and unfamiliar situations.

Second, *framing effects* occur when people's decision-making systematically depends on which logically equivalent description of outcomes or objects is presented to them. Framing effects violate the principle of a traditional model of economics, according to which logically equivalent descriptions should lead to identical decisions (Levin et al., 1998). For example, ground beef can be described as containing 75% lean meat or, alternatively, 25% fat meat (Levin and Gaeth, 1988). Although the two terms are logically equivalent (describing exactly the same sort of meat), they are not, what McKenzie and Nelson (2003) refer to as "informationally equivalent." A butcher who advertises his meat as 75% lean delivers his customers a slightly different message than his counterpart who advertises his meat as 25% fat. Specifically, by stating that the ground beef is 75% lean, the butcher may be highlighting a positive feature, the one that the customer presumably wants to maximize. The butcher is thus signaling that he is aware of the customer's desire and attempting to satisfy this need. The other butcher, who advertises his meat as 25% fat, is emphasizing a negative feature, indirectly signaling lack of concern for the customer's desires.

Finally, the *decoy effect* (also called the *attraction effect* or the *asymmetric dominance effect*) is a phenomenon in which consumers will tend to have a specific change in preference between two options – target and competitor – when also presented with a third option (the "decoy") that is inferior in all respects to both the target and the competitor (Huber et al., 1982). A decoy option is asymmetrically dominated because it is inferior in all respects to one option (e.g., the target), but only inferior in some respects and superior to another option (e.g., the competitor). The decoy effect violates the independence of irrelevant alternatives (IIA), in particular, an axiom which holds that if an individual prefers, for example, pizza to a hamburger, when considering the choice set (pizza and hamburger), then he or she also prefers pizza to hamburger in any other choice set (e.g., pizza, hamburger, and spaghetti). In other words, the relative probability of choosing pizza to the probability of choosing hamburger should be the same according to the IIA, independent of whether spaghetti is available or not (Luce, 1959; Ray, 1973). Thus, the decoy effect is one of the contextual factors which affect consumer decision-making and has been exploited by marketing and political strategies (Lehmann and Pan, 1994; Dhar and Glazer, 1996)

as well as in other contexts (Louie and De Martino, 2014). Louie and De Martino (2014) have further hypothesized that the decoy effect is the influence of a common biological mechanism, because similar effects have also been observed among multiple animal species.

In most of the experiments where cognitive biases have been demonstrated, participants are in situations where they cannot apply SIMS. This means that they need to construct a contextual model based on signals from the context, not from previously acquired beliefs. One possible explanation for this is that participants reveal their first impressions of a problem requiring decision-making in these cognitive bias studies, whereas decision-making in a real-world context is not grounds for first impression reactions. However, if the problem in the experiment allows use of prior knowledge and experience, cognitive bias effects decrease or disappear (List, 2003; Leong et al., 2017). In addition, in many cases, experimental control is often gained at the expense of ecological validity; participants cannot apply SIMS or change from SIMS to WOWS (and vice versa). These traditional experiments leave the question of what prior beliefs consumers use in a real market environment unanswered.

It is important to emphasize that WOWS is also rational from the CCDMM perspective. When a human has the tendency to look for relevance in a new or radically changed context, he or she tries to find a reference point in the uninterrupted commotion and interpret the situation in a meaningful way. Then, if a task includes the wording "the ground beef is 75% lean," an individual tries to interpret this wording from the point of view of either the experimenter and/or the butcher (Leong et al., 2017). In this way, context can "leak" information about the experimenter's intentions, and these signals are different in different options, despite options being logically equivalent. In short, contexts carry information beyond their literal content (McKenzie and Nelson, 2003).

Moreover, when considering the example of the daughter's birthday in **Figure 1**, it is intuitively difficult to conceive of how the anchor and other cognitive biases would affect an individual's decision-making in this context, because the contextual mental model and prior beliefs are related to "daughter's birthday party," a well-known cultural and social event. In addition, consumers usually possess existing prior knowledge about the commodities available in their living environment. Moreover, in situations like these, most people make decisions using SIMS. A general problem with traditional and behavioral economic models is that they concentrate on situations in which people need to apply WOWS, whereas most of the time, people in a real market context apply SIMS. It is plausible on a hypothetical level that traditional reinforcement learning procedures do not explain decision-making based on SIMS. Thus, there is a lot of space for new avenues of study in these directions.

The essential question is, how does a consumer rationally constrain his/her decision-making process in an information rich environment? The promising candidates for this "rational framing machine" in the brain are the reference point and the ecological rational approach. Kahneman and Tversky (1979) have conceptualized this as status quo, but recently growing evidence has suggested that the reference point is better described as an outcome expectation (Tymula and Glimcher, 2016; Suomala et al., 2017). The reference point is likely not a one-dimensional value scale, but a many-dimensional vector scale instead. Another direction of rational approach to cognitive biases comes from the ecological rational school founded by Gigerenzer (2008), who emphasizes that heuristics are rational most of the time, because a decision maker has limited time and cognitive resources. The reference point as both an outcome expectation and ecological rationality are consistent with the argument of this paper, that the context-specific expectations or prior beliefs constrain the interpretations of coming information of the specific context. More research is needed in order to describe and explain how consumers form reference points or use rational heuristics in a Gigerenzer sense in a real market context.

People parse their decisions based on what is similar and what is different. Current research emphasizes that humans cluster experiences together based on similarity in particular (Gershman and Niv, 2013). In a specific problem requiring decision-making, a consumer anticipates the structure of the problem's context by clustering structure, functions, and interactions of this context. Thus, humans organize their knowledge into discrete units called *chunks* based on regularities and similarities (Gershman and Niv, 2013; Gershman et al., 2017). In other words, consumers attempt to cluster their experiences based on the similarity of their interactions with this environment in the past. In addition to the representation of the physical context, similarity also works in the social environment. For example, a salesman who reported his own paint consumption to be similar to a customer's sold a larger quantity of paint (Brock, 1965). Furthermore, social influence is stronger when it originates in someone or something that is similar to the person being influences than from someone or something dissimilar (Gershman et al., 2017). The default assumption is that a consumer tries to start with SIMS. However, when consumers do not have any prior knowledge of a context or if the properties of a context change radically, it is necessary to create new categories, and they apply WOWS.

A rational consumer concentrates only on relevant marketing information. The brain's information processing is metabolically very costly (Lennie, 2003); our brain tissue is about seven times as "expensive" as the average tissue in our bodies (Tymula and Glimcher, 2016). Given a fixed neural activity budget, an efficient neural representation of a context would aim to increase discriminability between the most relevant inputs (Woodford, 2012). Then the essential question is what qualifies as relevant information and what is the simplest possible amount of information needed to achieve a result. The answers depend on the properties of the context and on the consumer's personal goals. For example, in an educational context, it is important to design multimedia so that it supports meaningful learning (Mayer, 2009). Then, the simplest possible amount of required information is determined by the learners' visual and verbal cognitive capacity and the essential knowledge relating to the learning content. In this

example, relevance is related to the most essential features of the educational context. The rational behavior is related to the scarcity of information, and the most important action in this process is to discard extraneous information and focus on the most relevant aspects of the context. The educational context is a solid illustration of an individual's decision-making because the goals of learning have been determined in a curriculum formed by educational policy-makers and educational experts, not by individual learners. However, if a learner does not feel that the learning content is relevant, his or her learning process will be disturbed.

In addition, the notion of relevance has specific meaning in models for human decision-making. Current research highlights that decision-making becomes relevant when the reason for a choice is to fit important personal goals (Csikszentmihalyi, 2000), which can shift across life stages (Bhattacharjee and Mogilner, 2014). Furthermore, relevance is defined as the set of contrasts a consumer is able to make with respect to the distinctions between options in the market (Ratneshwar et al., 1987). Thus, meaningfulness and relevance are the results of a person's capacity to interpret the properties of context in which they may make decisions. Ratneshwar et al. (1987) suggest that the relevance of stimulus objects in a given context is a function of the human capacity to concentrate on the most meaningful features of the environment in order to navigate it.

The anticipation of essential features of a market context helps a consumer to concentrate on its most relevant features. It is rational to begin with prior beliefs about the most regular and repeated properties of a context – that is, by applying SIMS. This assumption is consistent with the notion that the common goal of brain functions is to satisfy a "free-energy principle" (Friston, 2010) and approach with "efficient coding of subjective value" (Tymula and Plassmann, 2016; Polanía et al., 2019). When consumers encounter a new situation, they interpret it based on the information obtained from the situation, and apply WOWS.

CCDMM AND NEUROECONOMICS

Common knowledge holds that when purchasing a new house, a laptop, or a pair of shoes, people generally believe that conscious deliberation increases the likelihood that they will make the right choice. However, recent insights show that often the "deliberation-without-attention" leads to better decisions and satisfaction levels among consumers than does conscious deliberation (Dijksterhuis et al., 2006). Furthermore, current research has shown that behavioral science methods do not provide a sufficiently comprehensive picture of consumers' actual decision-making. However, work in the field of neuroeconomics has found promising evidence for more accurate methods of obtaining more exact knowledge from consumer behavior. Section Problems of Previous Consumer Science Methods describes the main problems of behavioral science methods; section The Brain's Valuation Network then describes how neuroeconomics provide more accurate ways of describing and explaining consumers' behavior from the CCDMM perspective.

Problems of Previous Consumer Science Methods

Self-reporting surveys and interviews are widely used tools for consumer research. Surveys of focus groups have been used to predict the success of new products, services, TV shows, ad campaigns, and even public health interventions (Scholz et al., 2017). These methods usually ask consumers about their intentions to change a behavior, to buy new commodities, their level of self-efficacy, or their beliefs about their own behavior (Venkatraman et al., 2015). Although the use of these self-reporting measures (questionnaires and interviews) are common, they are not perfect predictors of consumers' behavior in a real market context. Often the predictive power of these traditional methods is weak, as demonstrated by the fact that between 75 and 95% of all new products fail (Schneider and Hall, 2011).

The *verbal overshadowing effect* refers to the impairment of object recognition in subsequent tasks as a result of verbal explanation. For example, studies have shown that people who verbalized the pros and cons of an object made worse decisions because doing so prevented them from gaining access to their "gut feelings" about alternatives (Wilson and Schooler, 1991; Wilson et al., 1993). Furthermore, people demonstrated considerable levels of choice blindness, even for remarkably different tastes like cinnamon-apple and bitter grapefruit jams. This occurs because people verbalized their choice before researchers secretly switched the content of the sample containers (Hall et al., 2010). In addition, it has been confirmed that consumers' purchases of complex products were viewed more favorably when decisions had been made in the absence of verbalization and attentive deliberation (Dijksterhuis et al., 2006). Asking consumers how much they like something requires several mental and neurophysiological operations, including the initial processing of the stimulus, referencing similar items with which the consumer has experience, and projection of future benefit, all of which may be subject to the mental overshadowing effects of the experiment. Thus, while the act of rating something requires a verbal process, the brain response during the consumption of the good does not, and the latter may prove superior to rating approaches (Berns and Moore, 2012).

Therefore, it is not surprising that research methods based on linguistic processing do not yield a sufficiently precise understanding of consumer behavior. These traditional measures represent *post hoc* introspection about experiences from an earlier stimulus and could thus be distorted by a variety of factors, including higher cognitive processes and emotions (Venkatraman et al., 2015). Instead, current neuroeconomic research has shown that much of the normative attitudes and preferences expressed in life is processed subconsciously within the brain, and is not easily accessible for verbal self-report (Camerer et al., 2005; Venkatraman et al., 2015). This current approach has shown that decision-making involves, besides deliberative processes, many

subconscious mental and neurophysiological processes like concepts, sensory encodings, personal issues, situation-specific information, valuation, and emotions (Schröder et al., 2014; Tymula and Glimcher, 2016; Genevsky et al., 2017). These neurophysiological processes that give rise to behaviors occur in different regions of the brain simultaneously and are not always accessible to awareness (Cooper et al., 2015). Therefore, people often have a limited ability to consciously identify why they do what they do. It is difficult to argue, therefore, what their real personal preferences are. Despite these problems, the mental processes underlying decision-making are nevertheless represented in the brain (Berkman and Falk, 2013).

Neuroeconomics uses mainly brain-imaging techniques, in particular functional Magnetic Resonance Imaging (fMRI) to bypass the weakness of self-reporting and observe the brain activity that underlies particular consumer behavior. The fMRI scanner generates a strong static magnetic field and can reveal changes in blood flow when a participant is lying inside a large chamber, allowing researchers to study neural activity in the human brain almost in real time (Ashby, 2011; Suomala, 2018b). Therefore, it is no wonder that fMRI has grown to become the dominant measurement technique in cognitive neuroscience and neuroeconomics (Ruff and Huettel, 2014). FMRI measures the blood oxygen level-dependent (BOLD) signal, which is a measure of the ratio of oxygenated to deoxygenated hemoglobin. By using fMRI, researchers can infer which brain areas consume more oxygen and sugar than do inactive areas. These methods allow scientists to infer what happens within the brain when people are exposed to a certain product, advertisements, or other stimuli in a specific context. It is important though, to connect the neurophysiological data to real behavior, because human behavior is the result of coevolution of neurophysiological, mental, and social issues. There are also other neuroscientific techniques in consumer neuroscience and neuroeconomics (Suomala 2018a,b), however, as most of the scientific studies relevant to the topic were executed by fMRI, it is on this method that the articles focus.

The main task of the human brain is to effectively serve the host's biological, psychological, and cultural needs (Yamins and DiCarlo, 2016). Then the central insight of CCDMM is – in the same vein as evolutionary psychology and neurophysiology (Barkow et al., 1992; McDermott et al., 2008; Purves et al., 2015; Wilson et al., 2018) – that the essential task of the brain is not to copy facts but rather to help a person cope with everyday situations. This process can be best understood within the context of people living their everyday lives. Research in neuroeconomics has demonstrated that brain activity is a very dependable predictor of behavior. Using fMRI, scientists map the areas of the brain that respond to different types of stimuli in different contexts. These activity patterns in people's brains have been shown to be good predictors of individual responses to ad campaigns and likelihood of conforming to social norms (Scholz et al., 2017). Recent studies have also shown that brain activity is not only a predictor of individual behavior, but also a better predictor of a representative population's behavior than the traditional survey or focus group survey (Berkman and Falk, 2013; Genevsky et al., 2017). Measuring brain activity is therefore a new way to study consumers' underlying beliefs and hidden information about their true preferences. As the field of neuroeconomics expands, the integration of brain imaging underlying brain function will complement the use of traditional behavioral surveys in helping us to better understand consumers' decision-making in different contexts.

There are a number of reasons why neuroscientific methods and approaches should also be applied when developing better consumer theory, especially when examining the role of SIMS. In the following section, a neuroeconomic approach is presented from the CCDMM perspective.

The Brain's Valuation Network

Growing evidence from neuroeconomics shows that there are general decision networks in the brain, which count the total benefits (i.e., valuation) of different commodities in the market using a common neurophysiological currency. Whereas in many contexts, a number of variables (tone, color, characters, etc.) and attributes are involved in many market contexts and advertising messages, this complexity makes it almost impossible to isolate and measure the contribution of each variable using traditional methods. However, the brain's valuation network completes this demanding task and forms a net value of commodities and other items in different contexts.

The brain activation changes in this valuation network correlate with a commodities' values in a wide class of objects, from biological needs like food (Levy and Glimcher, 2012), clothing (Lim et al., 2013), and money (Glimcher, 2014) to abstract cultural values like charitable donations (Genevsky et al., 2013). The valuation network is made up of the Medial PreFrontal Cortex (MPFC), Ventral Striatum (VS), and Precuneus.

Studies have shown that small samples of participants' brain activation profiles in neuroscientific experiments can predict real behavioral chance in a real context. A sunscreen study, for example, demonstrated that when subjects were exposed to persuasive messages concerning sun exposure, neural signals in the MPFC, could be used to predict changes in sunscreen use 1 week following the experiment (Falk et al., 2010). Moreover, neural signals in the MPFC predicted variability in behavior more accurately than self-report measures alone (Falk et al., 2010).

In another example, Falk et al. (2011) examined smokers' neural responses to antismoking ad campaigns and subsequent smoking behavior. Consistent with the findings of the sunscreen study, when subjects were exposed to antismoke messages in the fMRI scanner, the MPFC activation in the brain more accurately predicted participants' inclination to quit smoking 1 month after the initial fMRI than traditional behavioral measurements. Thus, activation of the critical valuation area in the brain (the MPFC) may serve as an indirect marker of future behavioral changes. In addition, activity in the same region as the MPFC that predicted behavioral changes during message exposure also predicted population level behavioral changes in response to health messages and provided information that was not conveyed by participants' self-reports. Therefore, incorporating neural data with self-report measures may provide additional information for the development of predictive models.

These results extend the use of neuroimaging to predict other types of behavior, as opposed to simply predicting immediate effects (Berkman and Falk, 2013).

In the same vein, by using fMRI it is possible to predict the success of new songs on the market. When subjects listened to unknown popular music in the scanner and evaluated these songs behaviorally, brain activation in the Striatum predicted the success of the songs in a real market context over the next 3 years, whereas subjective likability – measured behaviorally – was not predictive of sales (Berns and Moore, 2012). In addition, the fMRI-communication study identified neural regions associated with successful message propagation in the brain's valuation network and in the brain's metalizing system (the Temporal Parietal Junction, TPJ; Falk et al., 2012). In this study, initial idea recipients' fMRI data profiles forecast an idea's success beyond the initial recipients to others whose brains were never examined and whose eyes are never exposed to the original information.

The above described fMRI studies suggest that neural responses to messages and commodities within the valuation network of the brain are not only predictive of purchase decisions for those individuals actually scanned, but may also be generalized to the population at large and used to predict the success of the sales of products and effectiveness of messages. Activity in the valuation network of the brain clearly predicts the real world success of different advertising campaigns, products, services, and social messages at the population level, whereas self-reports, which have been the target of consumer research for a long time, are not as successful in their predictions.

Human behavior is the result of the coevolution of neurophysiological, biological, and social issues. Similarity-based reasoning has been studied neurophysiologically, when participants recognize, classify, or judge objects (Gershman and Niv, 2013; Wirebring et al., 2018). These studies have shown that the humans have a proclivity to cluster experiences together into contexts based on similarity, and the brain's regions in the orbitofrontal cortex and precuneus play an essential role in similarity-based reasoning (Gershman and Niv, 2013; Wirebring et al., 2018). These findings are consistent with the basic idea of SIMS and the essential task of future research will be to compare whether consumers' decision-making has similar neurophysiological mechanisms to similarity-based reasoning. Relating to the WOVS, it is difficult to find studies in which consumers change their strategy from SIMS to WOWS according to CCDMM.

As stated previously, the main task of the human brain is to serve the host's biological, psychological, and cultural needs, and it serves not to copy facts but rather help a person cope with everyday situations. This is also the essential argument behind the CCDMM. The following section analyzes how the brain's valuation network acts according to demands of different contexts.

As seen from the perspective of Occam's Razor, consumer understanding is based on a very compressed representation of the world, and a rational consumer concentrates only on relevant marketing information. The brain's valuation network might work according to this rule and rank the patterns of a context from the most important and indifferent to the least important things. What the valuation network needs to do is to consider many different attributes of each option (such as color, size, taste, and health benefits) and of its personal host (like how hungry or thirsty we are), assess the value of each of the attributes within a relevant consideration set, and most importantly, to combine all of these things into one coherent value representation that allows an individual to make decisions and behave in rational way. Current new axiomatic characterizations of how and why the brain tries to minimize metabolic cost is consistent with this idea about rationality (Steverson et al., 2019). Therefore, the brain must behave as though it represents the values of many different kinds of rewards on a common scale for comparison and choice. Regarding mental context, prior beliefs, and physical market context (**Figure 1**), a consumer tries to apply previously acquired knowledge and experiences as much as possible, or in other words, tries to save energy by applying SIMS. This principle is consistent with the free energy principle of the brain (Friston, 2010).

Furthermore, it is rational from the CCDMM perspective that a consumer represents the most essential patterns of contexts, and is flexible between different contexts. Context sensitivity is also typical for valuation network operations. When it guides valuation and decision-making, this neural process is modulated by several factors including the construction of the choice set, reward history, and perceived outcome relative to a reference point. A critical question for further research is whether contextual valuation coding might underlie context dependency at the behavioral level (Louie and De Martino, 2014). There are also studies about the neural mechanisms underlying decoy (Hu and Yu, 2014; Chung et al., 2017) and framing effects (De Martino et al., 2006).

The basic premise of the CCDMM is that a consumer makes predictions about the basic structure and functions of a context and their relationship to it when solving decision-making problems. Three building blocks behind CCDMM – inductive inference, the principle of Occam's Razor, and Bayesian reasoning – work with predictions and help an individual to apply SIMS. Correspondingly, neuroeconomists measure brain activation in valuation networks while individuals evaluate information about various options, and then use that activation to predict subsequent behavioral outcomes, often over the course of weeks, months, or even years (Cascio et al., 2015; Knutson and Genevsky, 2018). Thus, the central tendency of the brain is probably to make predictions consistent with CCDMM.

DISCUSSION

This paper presents the CCDMM, which is a new interpretation of a consumer's decision-making from a contextual perspective. Whereas traditional economic models do not provide framework for connecting effects to environmental properties and are silent about decision-making context, traditional behavioral models maintain a consumer's context sensitivity as source of many cognitive biases. These models may seem contradictory and

mutually exclusive, however CCDMM is not an alternative for traditional models; rather it may be viewed as an extension of them. However, when modeling a consumer's decision-making with conceptual, computational, and mathematical tools, it is important to analyze this behavior in the real contexts. In some situations, a consumer faces one- or two-dimensional problem spaces, and it is suitable to apply "simple" economic utility functions (Jaynes, 2003). However, when one is faced – as is the case with most everyday problems – with an issue that includes many dimensions like emotions, attitudes, history of prior experience, and goals, then a fully adequate description of the human state and functions of mind would be better explained by studying brain functions. The brain has solved real-life problems during its evolutionary history and is able to adapt to a wide variety of contexts as a result. As such, it is possible to build a bridge between behavioral and neurophysiological approaches in order to better explain consumers' decision-making.

According to the CCDMM, a consumer is actively making inferences based on prior experience and expectations not only about observable goods, but also about whole context (Baum, 2004; Gershman and Niv, 2013; Büchel et al., 2014). In order to build a more plausible model of consumer decision-making, this paper has presented shared principles in the mechanisms underlying subjective decisions and sensory perception (Louie and Glimcher, 2012; Woodford, 2012; Polanía et al., 2019). Models from this line of research have suggested that subjective value construction resembles sensory perception in that they are derived by inference processes that exploit information about the relevant properties of the environment (Polanía et al., 2019).

The CCDMM is consistent at a fundamental level with the models of logical thinking and rational reasoning of Jaynes (2003) and Baum (2004), as well as with evolutionary theory (Barkow et al., 1992; Geary, 2005; McDermott et al., 2008; Wilson et al., 2018). This paper shares current assumptions that people are cognitive misers, who aim to save time and effort when navigating the world (Tymula and Plassmann, 2016; Steverson et al., 2019). However, at the same time the brain is not passively waiting to see what will happen, but is actively making inferences based on prior experience and expectations.

In addition, The Proactive Brain model created by Bar (2007, 2009) has similar properties to the CCDMM. Bar's model describes and explains the brain's representation, classification and understanding of different objects in contexts without links to decision-making and choice in a traditional economics sense. The basic visual cognitive mechanisms of Bar's model are the analogies, associations, and predictions, and it is the task of future research to determine how these mechanisms link to the decision-making mechanisms in the brain, when testing the CCSMM model behaviorally and neurophysiologically. Overall, the CCDMM provides suitable direction to further experimental, computational, and theoretical works.

The CCDMM has been described on conceptual levels. Whereas Bayesian reasoning is also a formal statistical tool used to study human decision-making, here it has been applied as conceptual framework. This conceptual framework gives directions for many testable hypotheses and experiments regarding consumers' decision-making. First, it is important to formalize the basic concepts of the CCDMM. Then it will be possible to test the model's operation computationally and experimentally. One interesting direction for research would be to examine what will occur when SIMS does not work in a specific situation, mental equilibrium gives way, and SIMS changes to WOWS. On a formal level, it is possible to count what the difference is between prior beliefs and the data in the context in which a consumer changes strategy from SIMS to WOWS. Graph theory (Markov et al., 2013; Suomala and Suomala, 2014) and the Bayesian network might be suitable tools for studying these ideas.

It has been argued that in most contexts, a consumer applies SIMS in an attempt to save mental and metabolic energy. However, on a general level, humans also have a tendency toward creativity and to produce new contexts. The limitation of the CCMDD is, therefore, that it does not describe a consumer's behavior from a creative standpoint. Thus, another possible direction for future research would be to combine creative processes with the CCMDD.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article.

AUTHOR CONTRIBUTIONS

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

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Looking at Aesthetic Emotions in Advertising Research Through a Psychophysiological Perspective

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Do usual commercials elicit the full spectrum of emotions? For this perspective paper, we posit that they do not. Concepts and measures related to the adaptive functions and well-being areas of emotion research cannot simply be transferred for use in advertising research. When a commercial elicits emotions, the emotions staged in the commercial must not be directly associated with the emotions felt by consumers when exposed to those commercials. This is why "aesthetic" emotions seem more appropriate than "utilitarian" emotions in advertising research, with the former generally felt more significantly than they are acted upon. Aesthetic emotions elicit limited physiological change, and they rely on the intrinsic pleasantness appraisal of commercials. Accordingly, pleasure and displeasure—as observed through expressive and subjective components of aesthetic emotion—often form the first and only step of commercial appraisal, and they are directed toward attitude formation rather than overt behaviors. Our preliminary psychophysiological study shows this by investigating the contributions of psychophysiological and self-reported measures of aesthetic emotions induced by commercials to explain attitudes toward advertisements. The results show that only two components of aesthetic emotion positively influenced attitudes toward the advertisements: expressive (measured by facial electromyography) and subjective (measured by the self-assessment manikin scale). Also, the subjective component of aesthetic emotion partially mediates the effects of the expressive components on attitudes toward the ads. Our exploratory study illustrates the relevance of focusing on aesthetic emotions in advertising research. It also shed new light on the contributions of the physiological, expressive, and subjective feelings components of aesthetic emotions in advertising effectiveness.

Keywords: advertising, consumer neuroscience, emotion, psychophysiology, cognitive appraisal, skin conductance, facial EMG, aesthetics

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CONSUMER EMOTION IN ADVERTISING RESEARCH: WHY DOES IT MATTER?

Studies in advertising research have investigated the effect of consumer's emotion on attitude toward the ad (Aad), attitude toward the brand, and purchase intention (e.g., Batra and Ray, 1986; Aaker et al., 1988; Derbaix, 1995). These studies implicitly assumed that commercials can elicit the full spectrum of emotions. We disagree with that assumption. First, concepts and measures related

to the adaptive functions and well-being areas of emotion research cannot simply be transferred to advertising research (Scherer and Zentner, 2001, 2008). Second, the emotions elicited by the affect-laden events depicted in commercials should not be confused with the emotions felt by consumers passively exposed to the commercials. Hyundai's 2016 Super Bowl commercial featuring "talking bears" illustrates our point. In this commercial, the bears attack hikers in a forest who find refuge in their car at the last second thanks to the new Hyundai remote start feature. For hikers, such a situation elicits "high-intensity emergency reactions involving a synchronization of many organismic subsystems," (Scherer, 2004, p. 241). This refers to utilitarian emotions. However, non-hiking consumers passively exposed to this commercial are not targeted by bear attacks. Actually, they are more likely to feel emotions that are oriented toward experiential phenomena rather than those "in the service of behavioral readiness" (Scherer, 2004, p. 244). This refers to aesthetic emotions.

For this perspective paper, we assume that consumers passively exposed to commercials experience *aesthetic* rather than *utilitarian* emotions.

THEORETICAL BACKGROUND AND SPECIFIC EXPECTATIONS

The cognitive appraisal theories (Arnold, 1960; Lazarus, 1982; Moors et al., 2013) state that the nature of emotion is determined by a cognitive appraisal. Emotions are extracted from appraisal of events that cause specific reactions in different people (Scherer and Zentner, 2001); it is not the events themselves that trigger an emotion but the way in which we interpret them (Haimerl, 2008).

Most of these appraisal processes are assumed to be automatic. Leading appraisal theorists postulate that cognitive appraisal is a precondition for emotion but do not equate appraisal with conscious cognition and place the cognitive component at the very onset of the emotional episode (Moors, 2009, p. 638). For example, work in neuroscience has shown that the relationship between cognitive appraisal and emotion is characterized by a cerebral process that simultaneously deals with emotional and cognitive functions (Fugate et al., 2011). Therefore, the distinction between appraisal and emotion is impossible to make consciously by individuals (Barrett et al., 2007, p. 386).

Within the framework of cognitive appraisal theories of emotion, the Component Process Model was developed with the aim of predicting the determinants of emotional episodes and to understand the cognitive mechanisms involved in the development of behavioral readiness (Scherer, 2009). In this model, the triggering of emotion and the determination of its characteristics rely on the subjective, continuous and recursive appraisal of an event perceived as relevant to the individual's goals. This appraisal process relies on the sequential evaluation of four main criteria—goal relevance, implication, coping, and normative meaning—which will result in physiological, expressive, and subjective responses at the origin of the individual's behavioral readiness (Scherer, 2009).

Goal relevance is the first step of stimulus appraisal process and plays a central role in determining the intensity of the subsequent emotional episode (Scherer, 1984; Frijda, 1986): "The more important the goal at stake, the stronger the ensuing emotion" (Moors, 2009, p. 640). That's why in our example, *utilitarian* emotions felt by hikers' can be stronger than the *aesthetic* emotions experienced by viewers. Utilitarian emotions are those emerging from the interpretation of events having important consequence for the wellbeing: "because of their importance for survival and wellbeing, many utilitarian emotions are high intensity emergency reactions" (Scherer, 2005, p. 706). But this is not the case for most of the emotions experienced when watching commercials.

Contrary to utilitarian emotions, aesthetic emotions "are triggered in situations that usually have no obvious material effect on the individual's well-being and only rarely lead to specific goal-oriented responses" (Scherer and Zentner, 2008, p. 596). According to Frijda and Sundararajan (2007, p. 232), aesthetic emotions "are more felt than acted upon and thus do not obviously manifest themselves in overt behaviors; [. . . they] may not show pronounced physiological upset [and] are often about complex events or subtle events aspects." However, this does not mean that aesthetic emotions are disembodied. Visual and auditory stimuli can induce changes in the consumer, either autonomic (i.e., activation of the autonomic nervous system) or expressive (i.e., activation of the somatic nervous system); therefore, they can define a specific emotional pattern through an appraisal process. For instance, studies have shown that watching commercials arouse both autonomic and expressive components of emotion (e.g., Aaker et al., 1986; Hazlett and Hazlett, 1999).

Aesthetic emotions are more reactive than proactive, and autonomic and expressive changes are primarily based on "the appreciation of the intrinsic qualities" of the stimulus (Scherer, 2004). For Kant (2001), aesthetic experience is disinterested pleasure highlighting the complete absence of utilitarian considerations (referenced by Scherer, 2005, p. 706). Frijda and Sundararajan (2007, p. 236) also suggest that pleasure and displeasure "often form the first step of appraisal, and on occasion they may form the only step" for eliciting aesthetic emotions. In other words, aesthetic emotions rely on an intrinsic pleasantness appraisal that directly affects the expressive component of emotion [e.g., facial electromyography (EMG) responses]. Even though autonomic responses (e.g., skin conductance responses) may be noticeable during aesthetic emotional episodes, they are not oriented toward adaptive action tendencies and display low amplitudes (see Scherer and Zentner (2008) for a discussion of empirical evidence).

In addition to the autonomic and expressive components, subjective feelings are another major component for investigating aesthetic emotions in advertising research. Within the framework of cognitive appraisal theories, subjective feelings represent a central component of emotion that serves as the basis for the conscious representation of emotional processes ("the subjectively experienced feelings of emotion"; Zentner et al., 2008, p. 497). Therefore, we assume that aesthetic emotions induced by commercials "should be studied as (more or less conscious) feelings that integrate cognitive and

physiological effects" (Scherer, 2004, p. 239). This is consistent with Aaker et al. (1988) who acknowledged that consumers' subjective feelings would be more appropriate for investigating advertising effectiveness.

To support our claim that usual commercials elicit aesthetic rather than utilitarian emotions, we investigated the structure of aesthetic emotional episodes and their active components during passive exposure to usual TV commercials. Usual TV commercials refer to ads with pleasant scenes, happy people, witty communication that characterize much of the advertising.

Even though autonomic (e.g., Aaker et al., 1986), expressive (e.g., Hazlett and Hazlett, 1999), and subjective (Aaker et al., 1988) components of aesthetic emotion have been studied in advertising research, it is noteworthy that there is no attempt to investigate the respective contribution of these coexisting components to the formation of subsequent attitudes. Therefore, we proposed an evaluation of the predictive power of those components on attitude toward the ad (Aad). Our specific expectations were the following:

1. Autonomic responses (skin conductance responses) induced by usual TV commercials do not influence Aad.
2. Expressive responses (facial EMG responses) induced by usual TV commercials do influence Aad: Increased activity in the cheek region has a positive effect on Aad, whereas increased activity in the brow region has a negative effect on Aad.
3. Subjective responses (subjective feelings component) induced by usual TV commercials have a positive effect on Aad.

As previously outlined, subjective feelings represent a central component of emotion that integrates all of the underlying emotional processes (Grandjean and Scherer, 2008). Accordingly, we expected that the expressive responses induced by usual TV commercials (but not autonomic responses) would be powerful predictors of subjective responses that in turn would be powerful predictors of Aad.

A PRELIMINARY PSYCHOPHYSIOLOGICAL INVESTIGATION OF AESTHETIC EMOTIONS ELICITED BY COMMERCIALS

To test our main hypothesis, we conducted a psychophysiological experiment during which 51 voluntary participants (21 female and 30 male) aged between 21 and 25 years (M = 23.06, SD = 1.25) were exposed to three video commercials (within-subject design).[1] Psychophysiological measurements of aesthetic emotion components (autonomic and expressive) were conducted in accordance to the methodological standards and the conditions to design and implement psychophysiological studies (Lajante et al., 2012, 2017; Lajante and Ladhari, 2019; Lajante and Lux, 2020; see **Figure 1**). Five respondents were eliminated because of a lot of missing values across items or identical responses to all items (self-reported measures) or because of technical problems during data recording (psychophysiological measures).

The results of our statistical analysis agree with our expectations (see **Table 1**). First, we tested the contribution of aesthetic emotion components (autonomic, expressive, and subjective) on Aad formation. The level of arousal measured by both the self-reported measure (SAM; 1–5 scale, M = 1.8, SD = 0.856) and EDA (ISCR; M = 0.3831, Min = 0.28, Max = 1.41) was very low. As expected, the autonomic component (EDA) did not predict Aad (β = 0.047, t = 0.542, p = 0.589, ns). This finding aligns with the view that usual commercials elicit emotional reactions that are more aesthetic than utilitarian. Thereafter, only one of our two somatic measures of the expressive component (pleasure) showed that facial EMG influenced Aad. *Zygomaticus major* activity had a significant positive effect on Aad (β = 0.279, t = 3.374; p = 0.00); however, *corrugator supercilii* activity did not appear to have a significant negative effect (β = -0.138, t = -1.667; p = 0.1). This finding is relevant considering the positive framing of commercials used in this study. Finally, the SAM indicated a positive effect of the subjective component on Aad (β = 0.534, t = 7.289; p = 0.00; Adj. R^2 = 28%).

Second, we tested the indirect effects of both the autonomic (EDA) and expressive (facial EMG) components of aesthetic emotion on Aad through the subjective component (SAM; Zhao et al., 2010). We did not observe any direct or indirect effects of the autonomic component (EDA) on either the subjective component (arousal measured through SAM) or on Aad. However, we observed that both measures of the expressive component (facial EMG) significantly predicted the pleasure dimension (SAM) of the subjective feelings component of aesthetic emotion (*zygomaticus major* activity: β = 0.328, t = 4.41; p = 0.00; *corrugator supercilii* activity: β = -0.157, t = -1.964; p = 0.05; Adj. R^2 = 13%). This result illustrates that the expressive component of aesthetic emotion (facial EMG) seems to be an antecedent of the pleasure dimension (SAM) of the subjective component. On the other hand, results indicated that facial EMG (only zygomaticus major activity) predict the arousal dimension (SAM) of the subjective feelings component as well (β = 0.179, t = 2.11; p = 0.04), which might be due to the intensity of the expressive component activation (Cacioppo et al., 1986). It offers psychophysiological validation and an objective foundation for this self-reported measure.

We then estimated the indirect effect between each measure of the expressive component (i.e., EMG activity of *zygomaticus major* and *corrugator supercilii*) and Aad (Preacher and Hayes, 2008; Zhao et al., 2010; Hayes, 2013). Based on a bootstrap analysis (95% confidence interval; CI), we first observed that the mean indirect effect between *corrugator supercilii* activity and Aad through the pleasure dimension (SAM) of the subjective feelings component was negative and significant (indirect

[1] Considering the technical constraints related to setting up an electrophysiological recording device (e.g., time spent to equip participants, cost of consumables), the size of our sample is not directly comparable to the size of samples of more common quantitative methods, such as those using questionnaires. A review of previous psychophysiological marketing research shows that the average sample size of studies similar to ours is 45 participants (Droulers and Lajante, 2015).

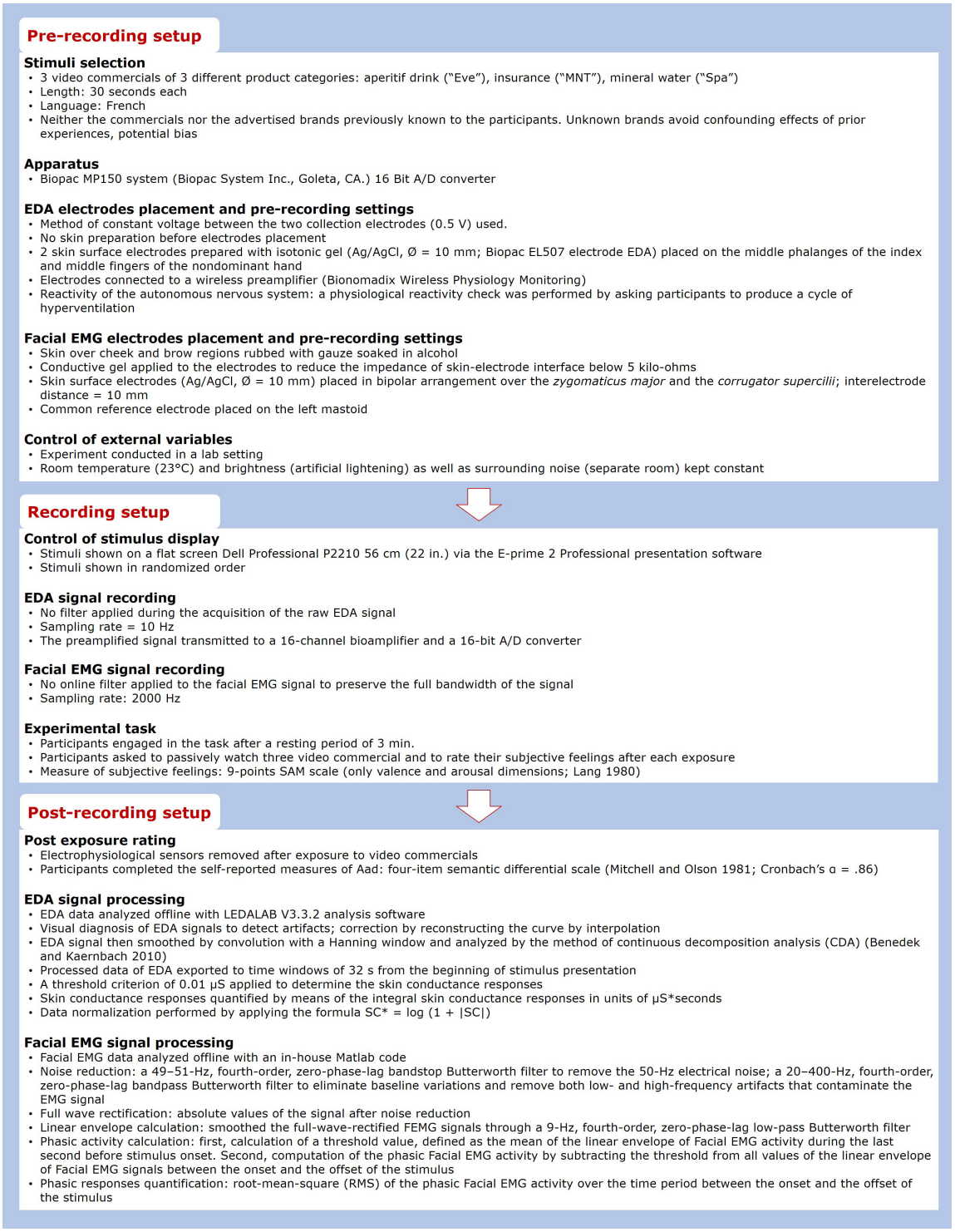

FIGURE 1 | Experimental setup of the psychophysiological study. The figure presents the settings before, during and after the signal recording of both electrodermal activity and facial EMG.

effect = −3.4748) with a 95% CI that excluded 0 (−7.1628, −0.9245). In the indirect path, an increase of one unit in *corrugator supercilii* activity decreased self-reported pleasure by a = −1.406 (p = 0.04). An increase of one unit in self-reported pleasure also increased Aad by b = 2.47 (p = 0.00). However, the direct effect was just slightly above the usual and arbitrary

TABLE 1 | Summary of the results.

	Direct effects of emotion components		
Independent variables	**Dependent variable – Aad**	**Dependent variable – SAM Pleasure**	**Dependent variable – SAM Arousal**
Psychophysiological measures			
EDA	β = 0.047, t = 0.542, p = 0.589 $R^2_{adjusted}$ = 0.00	β = 0.045, t = 0.524, p = 0.601 $R^2_{adjusted}$ = 0.00	β = 0.048, t = 0.562, p = 0.575 $R^2_{adjusted}$ = 0.00
EMG_zygomatic	β = 0.279, t = 3.374; p = 0.00	β = 0.328, t = 4.41; p = 0.00	β = 0.179, t = 2.11; p = 0.04
EMG_corrugator	β = −0.138, t = −1.667; p = 0.1 $R^2_{adjusted}$ = 0.09	β = −0.157, t = −1.964; p = 0.05 $R^2_{adjusted}$ = 0.13	β = −0.056, t = −0.658; p = 0.512 $R^2_{adjusted}$ = 0.02
Self-report measures			
Pleasure	β = 0.540, t = 7.375; p = 0.00		
Arousal	β = 0.095, t = 1.295; p = 0.198 $R^2_{adjusted}$ = 0.28		
	Indirect effect between each measure of the expressive component on Aad		
	EMG_zygomatic → Pleasure → Aad	Complementary mediation	
	EMG_corrugator → Pleasure → Aad	Indirect mediation	

threshold of significance (c = −6.19, p = 0.06). As a × b × c was positive and significant (p = 0.00), only an indirect mediation was at work. Second, we observed that the mean indirect effect between *zygomaticus major* activity and Aad through the pleasure dimension (SAM) of the subjective component was positive and significant (indirect effect = 3.8409) with a 95% CI that excluded 0 (2.1883, 6.1428). In the indirect path, an increase of one unit in *zygomaticus major* activity increased self-reported pleasure by a = 1.6472 (p = 0.00). An increase of one unit in self-reported pleasure increased Aad by b = 2.3318 (p = 0.00). The direct effect was significant (c = 6.61, p = 0.00). As a × b × c was positive and significant, there was complementary mediation at work.

These results reveal that the indirect effects of the expressive component of aesthetic emotion (facial EMG) on Aad are statistically significant. The pleasure dimension (SAM) of the subjective component of aesthetic emotion partially mediates the effect of facial EMG on Aad. Therefore, the self-reported and psychophysiological measures of aesthetic emotion are not interchangeable. Both are relevant to evaluate the impact of positive aesthetic emotions on Aad.

WHAT DOES AESTHETIC EMOTION MEAN FOR INVESTIGATING CONSUMER EMOTIONS IN ADVERTISING RESEARCH?

In this perspective paper, we highlight the distinction between utilitarian and aesthetic emotions. To the extent that usual commercials do not seem to have obvious material effect on well-being and rarely lead to specific goal-oriented responses (e.g., fight or flight), the actual generated emotions—as shown by self-reported and psychophysiological measures—do not create important modifications in the autonomic nervous system that are largely devoted to behavioral readiness during utilitarian emotion. Therefore, our results encourage to focus on aesthetic emotions in advertising research.

Our results also shed new light on the respective contributions of the physiological, expressive, and subjective feelings components of aesthetic emotion elicited by usual commercials on Aad. Although researchers recognize the multi-component nature of emotions, most investigations have been restricted to the impact of the subjective component of emotion on Aad, with both elements being verbally measured. The current study departs from previous research by focusing on the respective contributions of autonomic, expressive, and subjective components of aesthetic emotions elicited by commercials in explaining Aad.

As expected, the autonomic component of emotion does not affect Aad, neither the physiological nor self-report measures. This might be due to the aesthetic nature of emotional episodes elicited by commercials. As stated by Mulligan and Scherer (2012, p. 353), the intensity of bodily reactions varies "and some emotions, such as [. . .] aesthetic emotions, may have much subtler bodily manifestations than the utilitarian, survival emotions such as fear, anger, or disgust."

Contrary to the arousal level of aesthetic emotion, the somatic (expressive component) as well as the self-reported (subjective component) levels of pleasure positively influence Aad. This result aligns with our assumption that aesthetic emotions are primarily derived from the appreciation of "the intrinsic qualities" of the stimulus (Scherer, 2004, p. 244) that contribute to the formation of consumer attitudes. The subjective feelings of pleasure partially mediate the effect of facial EMG on Aad (i.e., the subjective component of pleasure partially rests on expressive motor reactions). Therefore, self-reported emotions may reflect actual emotional episodes better than a simple manifestation of social desirability or the use of display rules that voluntarily alter affective reactions. By dealing with aesthetic emotions in the case of commercials (Scherer, 2004), we determined that subjective feelings of pleasure/displeasure represent genuine perceptions

according to their facial EMG measurement and partially mediate the effects of facial EMG on Aad. In this exploratory research we confirmed the sequential perspective proposed by Scherer (1984) by showing that the expressive (motor) component precedes and explains the subjective feelings component of emotion.

On a methodological note, our results highlight the automatic and corresponding background of pleasure assessed iconically (i.e., SAM scale). The consideration of both sides of the same coin led us to validate an iconic measure of pleasure. However, we did not find similar correspondence or consistency in the case of arousal, presumably because we registered particularly low levels of autonomic arousal (through EDA) for aesthetic emotions. Therefore, facial EMG might be more informative than EDA for measuring aesthetic emotions in advertising research. In addition, this research confirms that self-reported and psychophysiological measures are more complementary than mutually exclusive.

Finally, an important implication that emerges from the results of this research is that special attention must be paid to the merits of each method. For example, to estimate ad effectiveness, communication agencies and neuromarketing companies often use devices like a wristwatch that measures arousal given this device's ease of use. However, the current research shows that the evaluation of usual ads mainly relies on pleasure, not on arousal. So, special attention must be paid to their ability to induce pleasure when pretesting usual ads.

LIMITATIONS AND FUTURE DIRECTIONS

This perspective paper is exploratory, and its results must be tempered to some extent by limitations that deserve to be addressed in further research.

First, we use a limited set of only three commercials. Replications with less sales-oriented commercials (e.g., cause-related) could reveal how generalizable our results may be. Replications with more engaging products (e.g., cars, luxury goods) would also be useful for testing the robustness of our findings. Moreover, it is possible to elaborate a strategy aiming to elicit instrumental behavior through emotional reactions using "endorsers" describing how good they feel after quitting their "smoking addiction", or how irrational they were to keep on smoking too many years with severe health problems as a consequence. Nowadays there are campaigns to adopt behavioral measures (e.g., social distancing and/or wearing a mask) to protect people against COVID-19. However, this type of advertising campaigns is more the exception than the rule.

Second, it is widely accepted that the face is central to a system of rapid, emotion-revealing signals, and arousal is often described as a key dimension of an emotion. Using physiological tools (facial EMG and EDA) requires neither retrospection nor introspection. However, the tools used in this study are extremely difficult to implement in a naturalistic environment. To advance toward ecological validity, forced exposure must be reduced by using a real program in which commercials are embedded.

Third and finally, this research focuses on affective independent variables. In the future, it may be important to integrate variables of a more cognitive or evaluative type—including recall, recognition, or evaluation of the arguments and elements of ad execution to attain a more comprehensive view of the topic. Focusing on the elements of execution of the commercial seems particularly essential to the extent that, as stressed by Scherer and Zentner (2008, p. 596) "in the case of aesthetic emotions appraisal tends to be more intrinsic to the visual or auditory stimulus, based on forms and relationships."

AUTHOR'S NOTE

This research relies on ML's Ph.D. dissertation.

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 École Universitaire de Management de Rennes. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ML conceptualized the study, set up the psychophysiological study, processed the physiological signal, performed descriptive statistics, wrote the draft, and revised the final draft. OD was the supervisor of the Ph.D. thesis on which this research relies and contributed to all the stage of the development of the present research. CD and IP contributed to the conceptualization of the study, performed the statistical data analysis, and participated to improve the manuscript. All authors contributed to the article and approved the submitted version.

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Consumers Emotional Responses to Functional and Hedonic Products: A Neuroscience Research

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Over the years, researchers have enriched the postulation that hedonic products generate deeper emotional reactions and feelings in the consumer than functional products. However, recent research empirically proves that hedonic products are more affect-rich only for some consumer segments or for specific consumption contexts. We argue that such inconsistency may derive from the nature of the emotions assessed that is strictly dependent on their empirical measurement and not from the mere existence of emotions themselves. Self-reported methods of evaluating consumer experience, on which prior studies are grounded, only assess conscious emotions the consumer can recognize and report, but not unconscious feelings, happening without individual awareness. The present work takes this challenge by conducting a laboratory experiment in which subjects are exposed to both a utilitarian product and a hedonic product. Physiological measures have been adopted to investigate unconscious emotional responses and self-reported measures to assess conscious emotions toward the products. Specifically, physiological data regarding the subjects' cardiac activity, respiratory activity, electrodermal activity, and cerebral activity have been collected and complemented with a survey. Results confirm that both functional and hedonic products generate emotional responses in consumers. Further, findings show that when a consumer is exposed to a functional product, the physiological emotional responses are disassociated from the self-reported ones. A diverse pattern is depicted for hedonic products. We suggest an alternative explanation for the apparent lack of affect-rich experiences elicited by functional products and the need to reconsider emotional responses for these products.

Keywords: emotions, functional product, hedonic product, neuroscience, physiological signals

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INTRODUCTION

As a large body of research documents, consumers' evaluations of new products are not purely utilitarian but dependent on the emotions and involvement elicited by the offer (Bagozzi et al., 1999; Kempf, 1999; Allen et al., 2005; Hassenzahl, 2018). Emotional responses constitute predictable and impactful drivers of decision making with regularities in the mechanisms through which they influence product evaluation (Lerner et al., 2015; Bettiga and Lamberti, 2017). Research on product adoption and consumption mainly argues that such emotional responses are processed differently

by individuals according to the mainly hedonic or utilitarian/functional nature of the product they are evaluating (Hoch and Ha, 1986; Batra and Ahtola, 1991; Kempf and Smith, 1998; Ren and Nickerson, 2019; Yang et al., 2020). Hedonic products refer to objects consumed mostly for affective or sensory fulfillment aim, while utilitarian products are connected to more functional and practical benefits (Woods, 1960; Strahilevitz and Myers, 1998; Huber et al., 2018). Although this distinction is less than unequivocal (Holbrook and Hirschman, 1982), there appears to be a consensus that a main utilitarian product affects differently cognition and emotions than a hedonic product (Kempf, 1999). Hedonic products have been argued as being more affect-rich than those consumed for utilitarian purposes (Pham, 1998; Malhotra, 2005; Baghi and Antonetti, 2017). Research affirms that they generate greater arousal (Kempf, 1999), pleasure, and engagement (Kivetz and Simonson, 2002; Zheng and Kivetz, 2009; O'Brien and O'Brien, 2010) than utilitarian ones.

Given that, academicians and marketers have proposed different communication approaches for the two product typologies, assuming that emotional communication would be more effective for a hedonic offer (Johar and Sirgy, 1991; Rossiter et al., 1991; Batra and Stephens, 1994). However, recent research sheds doubts on the inherent difference in the emotions generated by hedonic versus utilitarian products, showing that hedonic offer generates greater emotions only for some customer segments (Drolet et al., 2007) or for specific interaction modes (Liao et al., 2016). Other studies found that emotional responses (e.g., Henning et al., 2012) and consumer responses (Vila-López and Küster-Boluda, 2018) do not differ for hedonic and functional product evaluation.

We propose that such discrepancy may derive from the nature of the emotions assessed, which is strictly dependent on their empirical measurement. Research typically measures emotions through self-reported techniques, such as surveys (e.g., Henning et al., 2012; Liao et al., 2016). Self-reported techniques, however, have shown significant limitations when it comes to assessing human reactions to stimuli and purchase patterns (Groeppel-Klein and Baun, 2001; Ait Hammou et al., 2013). Consumers, indeed, are typically unable to describe their emotional processes, given the subconscious mechanisms of which individuals are not aware of and thus cannot report (Berridge and Winkielman, 2003; Ivonin et al., 2013). These methods can only catch what consumers report, so the conscious emotions that the consumer can recognize and describe. However, self-reported methods cannot measure the unconscious feelings and emotions the individual experiences but is not able to account. For these reasons, several researchers highlight the need to measure physiological unconscious emotions that go beyond the subjective felt ones (Oatley, 1992; Bagozzi et al., 1999; Chamberlain and Broderick, 2007).

This research attempts to address such concern by assessing both the physiological (unconscious) and the self-reported (conscious) emotional reactions generated by hedonic and utilitarian products, given the importance of emotions in product adoption and consumption (Chaudhuri et al., 2010). We examine the influence of the product nature (functional and hedonic) on a consumer's affective reactions of pleasure, arousal, and involvement through both physiological techniques (electroencephalography, heart rate, breath rate, and skin conductance) and self-reported instruments. With this study, we aim at providing theoretical and empirical evidence on the conscious and unconscious emotional responses generated by hedonic and utilitarian products. Further, we provide implications of the use of physiological techniques in the assessment of a consumer's experience with new products.

THE ROLE OF EMOTIONS IN PRODUCT EVALUATION

Pleasure, Arousal, and Involvement

Emotions may have two conceptualizations: discrete emotions, identified as individual and basic entities such as happiness, surprise, and sadness; or global feelings, identified in the two dimensions of arousal and pleasure. The validity of discrete emotions has been called into question by several researchers, as their identification was considered incoherent and trivial (Chamberlain and Broderick, 2007). In light of such criticisms, research has mainly focused on the global feelings of pleasure and arousal (Mehrabian and Russell, 1974), enabling a variety of measurement techniques with better results than discrete emotions assessment (Chamberlain and Broderick, 2007).

Pleasure (or valence) reflects happiness and satisfaction, while arousal conveys excitement, stimulation, and bodily activation. From a physiological viewpoint, arousal is a central component of behavior and a driver of decision-making processes (Groeppel-Klein, 2005). Arousal reflects an active body reaction; thus, it is closely related to attention to relevant outside stimuli and their processing (Groeppel-Klein, 2005) and has been acknowledged as a direct expression of involvement (Chaudhuri, 2002). Heightened arousal, indeed, has been found as a consequence of product involvement (Mitchell, 1980). The two emotional reactions, as suggested by literature (Chaudhuri, 2002; Groeppel-Klein, 2005), may be indeed strongly connected. Physiologically, involvement is identified as "the ability to focus on certain aspects of the environment while ignoring others" (Venkatraman et al., 2015, p. 438). It reflects the intrinsic interest and needs gratification that the consumer searches in the product (Zaichkowsky, 1985; Mittal and Lee, 1989; Batra and Ahtola, 1991). Arousal can have a positive or a negative valence: for instance, an individual showing high arousal can be either positively excited or highly irritated or upset. This view has been widely confirmed through empirical studies (Baker et al., 1992; Ward and Barnes, 2001) that showed the distinct nature of the arousal–relaxed and pleased–unpleased dichotomy and highlight the necessity to measure both dimensions to gather a complete understanding of consumer reactions.

Measuring Emotions

The existence of an emotional state can be inferred by the means of physiological measures, self-report measures, or behaviors (Lang, 1968; Öhman, 1986). Marketing and consumer behavior research traditionally adopted self-reported measures to assess

emotions, such as unipolar or bipolar scales on surveys (e.g., Mehrabian and Russell, 1974). A review of the main self-reported methods used in research is presented by Chamberlain and Broderick (2007). However, self-reporting may not reflect the real feelings that consumers experience (Ait Hammou et al., 2013) as individuals are typically unable to describe their emotional processes given the subconscious components that they cannot take into account (Kihlstrom, 1990, 1992; Kihlstrom et al., 2000; Berridge and Winkielman, 2003; Smith and Lane, 2016; for a review, see Robinson and Clore, 2002). Emotional responses, indeed, can be consciously experienced when they are generated by the identification of the eliciting cause. This happens through the recognition of the product that generates the emotions—e.g., a man pleased by a new pair of beautiful shoes (Kihlstrom, 1990). Or they can be unconscious when they are consciously experienced but without identification of the eliciting cause (misattribution) or generated but not consciously recognized (Kihlstrom et al., 2000). This is, for instance, the case of a consumer feeling anxious while using a new laptop but without knowing why. Despite the fact that prior research mostly failed to assess such unconscious emotions, it is widely acknowledged that most of the feelings that determine thought and behavior occur without awareness (Zaltman, 1997). While self-reported emotions are cognitive evaluations made *a posteriori*, physiological measures are not affected by the cognitive influences (Figner and Murphy, 2011). These measures can unveil the unconscious reactions of consumers to stimuli (Figner and Murphy, 2011) for which individuals are typically not aware of and hence not able to fully explain and report them (Fortunato et al., 2014). Physiological techniques have been confirmed successful in predicting consumer responses in a variety of contexts (Guixeres et al., 2017; Brás et al., 2018; Lin et al., 2018b; Sung et al., 2019).

EMOTIONS TOWARD HEDONIC AND UTILITARIAN PRODUCTS

Research conventionally makes a distinction between hedonic and utilitarian products (Kempf, 1999; Kim and Morris, 2007; Lin et al., 2018a; Amatulli et al., 2020). Hedonic products are consumed mostly for affective or sensory fulfillment aim, while functional products for utilitarian goals (Woods, 1960; Strahilevitz and Myers, 1998; Kivetz and Simonson, 2002; de Witt Huberts et al., 2014; Lu et al., 2016). Hedonic goods are associated with fun, pleasure, and excitement (Khan et al., 2004). Typical examples of such products are perfumes, flowers, luxury watches, and sports cars. Utilitarian goods are primarily instrumental, and consumption is driven by functional aspects, such as for detergents, home security systems, or personal computers (Holbrook and Hirschman, 1982; Strahilevitz and Myers, 1998; Wertenbroch and Dhar, 2000).

Hedonic and utilitarian products have been associated with different consumer reactions and behaviors (Holbrook and Hirschman, 1982; Batra and Ahtola, 1991). Research has quite consistently argued that feelings are weighed more heavily under hedonic than utilitarian consumption goals (Pham, 1998; Malhotra, 2005). Products consumed for hedonic purposes have been acknowledged as more affect-rich and evoking feeling-based evaluations (Pham, 1998; Kempf, 1999; Malhotra, 2005). Research argued that hedonic product experiences lead to stronger emotional responses of arousal (Kempf, 1999; Fiore et al., 2005), pleasure, and engagement (Kivetz and Simonson, 2002; Zheng and Kivetz, 2009; O'Brien and O'Brien, 2010) than utilitarian ones. As a result, researchers and practitioners suggested different communication strategies according to the nature of the product marketed, assuming that affective communication evokes more positive consumer responses for a hedonic offer (Johar and Sirgy, 1991; Rossiter et al., 1991; Batra and Stephens, 1994). Emotional and value-related communication has been claimed as more relevant for such products (Johar and Sirgy, 1991; Rossiter et al., 1991), and ad liking seems connected to ad recall for hedonic but not for utilitarian objects (Youn et al., 2001). Overall, research moved toward the conclusion that the use of emotional appeal is desirable for hedonic products, while for utilitarian ones, it is not advised (Rossiter et al., 1991; Youn et al., 2001).

However, recent studies shed doubts on the inherent difference in the emotions generated by hedonic versus utilitarian products. Drolet et al. (2007) found that young adults have more positive attitudes toward and better recall of affective ads for hedonic products than utilitarian ones (for which rational ads work better), but the elderly have better recall and more positive attitude toward affective ads irrespective of the nature of the product advertised. Liao et al. (2016) proved that hedonic products, presented through an online interface, generate higher pleasure than utilitarian products but only in specific interaction conditions. They detected no differences, however, in the arousal dimension. Similarly, Sharma and Chan (2017) found mixed evidence on the moderating effect of product nature on counterfeit product purchase behaviors. Henning et al. (2012) and Bettiga and Lamberti (2018) established that emotions are relevant to both hedonic and functional product evaluations.

Such inconsistency in results may be generated by the empirical assessment of the emotions themselves, typically measured through self-reported techniques, by asking consumers to report the feelings they experienced. When interacting with hedonic products, indeed, consumers may devote higher attention to the emotional outcome of the consumption episode and emotions elicited by such interaction (Neelamegham and Jain, 1999). For certain products, such as movies, the emotional outcome may itself be the objective (Neelamegham and Jain, 1999). As emotions are perceived to be more important for hedonic consumption motives, consumers may pay more attention to their emotional reactions for hedonic products (Pham, 1998). Even when emotional responses are elicited similarly in both hedonic and utilitarian consumption, consumers are more likely to infer that their emotional responses have been elicited by the product itself (and not by other contextual elements) only for hedonic consumption (Henning et al., 2012). Thus, it is plausible that unconscious emotions are translated in consciously experienced emotions for hedonic products only, where there is an identification of the eliciting cause. Hence, we argue that the attribution of

emotions mainly to hedonic products in mainstream research (e.g., Kempf, 1999) may be due to the conscious recognition and reporting of such emotions by consumers and not by the magnitude of real emotions experienced. For utilitarian products, conversely, consumers may not translate unconscious emotions in conscious, thus reportable, feelings, regardless of the real emotions experienced.

Grounding on this discussion, we expect that both functional and hedonic products generate emotions. However, such emotions may not be consciously recognized in utilitarian consumption scenarios, thus generating a misalignment between unconscious emotions and conscious emotions. Conversely, we expect that the unconscious emotions elicited by a hedonic product may be recognized at the conscious level. In other words, we posit that consumers do experience and are able to report emotions for hedonic products. Hence, we expect an alignment between physiological unconscious emotions and self-reported, thus conscious, ones. On the contrary, for functional products, consumers do experience emotions but are not able to report them; hence, we expect a misalignment between physiological and self-reported emotions. More formally, we propose:

> **H1:** *There are no significant differences between the emotional reactions of (H1a) arousal, (H1b) pleasure, and (H1c) involvement generated by hedonic and functional products.*
>
> **H2:** *For functional products, conscious and unconscious emotions of (H2a) arousal, (H2b) pleasure, and (H2c) involvement are misaligned.*
>
> **H3:** *For hedonic products, conscious and unconscious emotions of (H3a) arousal, (H3b) pleasure, and (H3c) involvement are aligned.*

MATERIALS AND METHODS

Laboratory Experiment

A laboratory experiment was conducted inside a university bioengineering laboratory to evaluate a consumer's responses toward a functional product and a hedonic product. The experimental base was composed of 21 subjects (14 males, 7 females) aged between 22 and 25 years old. The narrow age range assures the full comparability of physiological data collected, as they may vary with age (e.g., Hayano et al., 1990). The sample size is in line with prior experiments adopting biometric measures (Vecchiato et al., 2012). Demographic statistics are reported in **Table 1**. We used a body scale as a functional product and an MP3 player as a hedonic product, according to prior research (Bettiga et al., 2017a), showing a significant difference in the perceived nature of the two products. The brands chosen were unfamiliar in the market where the experiment was conducted to avoid extra-experimental sources of variance caused by brand-related attitude. Half of the subjects were exposed firstly to the functional product and then to the hedonic product. The other half of the subjects were exposed firstly to the hedonic product and then to the functional product. Randomization was necessary to avoid possible confounding effects.

TABLE 1 | Demographic statistics.

Sex	Male 66%	Female 33,3%	
Age	Min 22	Average 23.6	Max 25
Study title	Bachelor's degree 85.7%	Master's degree 14.3%	
Employment	Students 95%	Nonstudents 5%	
Nationality	Italian		

N = 21.

All volunteers were welcomed and briefly explained what the experimental protocol would have consisted of and were told they could withdraw from the experiment at any time. Subjects were instructed that the study aimed to assess their evaluation of commercial products and that, after the product examination, they will be asked to complete a questionnaire to record their evaluation. This procedure, according to prior research (Kempf and Smith, 1998), serves to prime the respondents to engage in product evaluation. During the study, subjects were comfortably seated in front of a PC monitor used for stimuli delivery. During the whole experiment, we collected the subjects' cardiac activity (electrocardiogram, ECG), respiratory activity, electrodermal activity (EDA), and brain activity (electroencephalographic signals, EEG) to detect their unconscious emotions of arousal, pleasure, and involvement. Further, we assess, through a questionnaire, self-reported measures of arousal, pleasure, and involvement. The use of both physiological and self-reported methods allows testing the existence and the alignment/misalignment of conscious and unconscious emotions. To assure the absence of any kind of social influence or disturbance, the experiment was performed on one subject at a time. The study was organized into four consecutive phases:

I. A 2-min-long phase of mathematical calculations aimed at increasing the participants' level of stress.
II. A 3-min-long phase of rest, in which the volunteers were asked to stare at a picture and to relax. This procedure was necessary to assess a baseline for each respondent, a condition against which physiological changes during the experiment can be compared.
III. The browsing of an *ad hoc* webpage displaying information and pictures about a commercial product (a functional product and a hedonic product). This phase could last at most 5 min.
IV. The filling of a questionnaire to collect self-reported measures about the product experience, plus individuals' demographic information.

The first three phases of the experimental protocol were implemented using the Matlab software (Matlab version R2014a, The MathWorks, Inc.). During phase III, all participants could freely browse each webpage for the time they needed within the 5-min-long duration of this phase. The 5-min time limit serves to minimize underexposure or overexposure to one type of experience and yet provide enough duration not to affect

the inherent advantages associated with the virtual experiences (Daugherty et al., 2008). The provision of *ad hoc* pages assures that (i) respondents do not browse other webpages or get distracted by web banners and pop-up as it may happen while browsing real webpages and (ii) we could design identical webpages for the two products under test to avoid differences in the virtual experience. Product webpages had the same layout, colors, and interaction possibilities. Each webpage had four links: home page, image, information, and supplementary information. Each subject could visit each link all the time he or she wanted.

Measurements

Confounding and Manipulation Variables

We measured two confounding variables: product perceived diagnosticity and product perceived nature. Product perceived diagnosticity represents the consumer's perception of the ability of a trial to help him or her understand the product. Diagnosticity should be perceived equal for the two products (i.e., both virtual interactions offer representative, credible evidence of the product and its attributes). This check guarantees that both webpages offer enough informative experience, as diagnosticy is able to affect product experience processing (Hoch and Ha, 1986; Kempf and Smith, 1998). Product diagnosticity was assessed via a single-item scale by asking, "Overall, how helpful would you rate the website navigation you just had in judging the quality and performance of the product?" Responses were assessed on a 1–7 scale with the endpoints labeled "not helpful at all" and "extremely helpful" (Kempf, 1999).

Secondly, to confirm that our manipulation of product nature was successful, we asked participants to rate each product on a 7-point scale according to perceived functional versus hedonic characteristics. This approach is similar to the one adopted in prior studies (Kempf, 1999). Specifically, we asked, "Would you characterize the [product] as primarily a functional product or an entertainment/enjoyable product?" with a 7-point scale, with 1 being "primarily for functional use" and 7 being "primarily for entertainment use" (Kempf, 1999).

Physiological Measures

Physiological signals were collected during the whole experiment. Specifically, we collected data regarding the subjects' cardiac activity (electrocardiogram, ECG), respiratory activity, and EDA using a unique device (ProComp Infiniti encoder, Thought Technology Ltd., Quebec, Canada) to assess the subject's level of arousal. The ECG signal was acquired using three disposable electrodes placed on the volunteer's chest (the negative and the ground electrodes were placed on the right and left shoulder, respectively, while the positive electrode was placed above the right iliac spine). The respiratory activity was measured using a sensorized belt to be fastened around the participant's chest. The EDA signal was acquired using two electrodes sewn inside Velcro straps to be fastened around the second and third fingers of the participant's nondominant hand. The EDA signal is a measure of the skin's ability to conduct electricity and represents changes in the sympathetic nervous system. A broad consensus exists among researchers that have recognized changes in heart rate, breath rate, and EDA as a reflection of changes in the level of activation generated during an emotional episode (Dawson et al., 2007; Sequeira et al., 2009; Dawson, 2011; Boucsein, 2012).

Furthermore, we collected data regarding the subjects' brain activity (electroencephalographic signals, EEG) using the SD LTM EXPRESS headbox (Micromed S.p.A, Mogliano Veneto, Italy) and a 61-channel head cap. Specifically, the cap was placed above the subject's head, and a conductive gel was used to acquire the brain signals from 28 channels (Fp1, FPz, FP2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2, AF7, AF3, AF4, AF8, F5, F1, F2, F6). We selected these specific channels as they enable the measurement of quantitative indexes of attention and pleasantness (Vecchiato et al., 2010, 2011, 2012).

Physiological Data Elaboration

All physiological data were elaborated using appropriate methods of signal processing following the relevant literature. As physiological measures for three subjects were not properly recorded, we did not consider these subjects in further elaboration, proceeding with analysis on a sample of 18 (11 males, 7 females) subjects. The elaborated data were then used to compute quantitative indexes to be correlated with the results of the questionnaire. Specifically, the heart rate variability (HRV) was obtained from the ECG signal as the time series of the heartbeat time intervals (Pan and Tompkins, 1985). The combined effect of cardiac and respiratory activity was taken into account using a bivariate time-variant autoregressive model (Barbieri et al., 1997, 2002; Mainardi et al., 1997), from which a quantitative feature (PSDc/r) describing the amount of HRV signal driven by respiration was computed (Bianchi et al., 1990). HRV and PSDc/r were obtained on a beat-to-beat base; the values were normalized by subtracting their average value during the baseline and by dividing by their standard deviation during the baseline. For this purpose, we used the last minute of the 3-min-long baseline phase. After that, the normalized HRV and PSDc/r beat-to-beat values were averaged across phase III to obtain one single value for each index. HRV_{III} and $PSDc/r_{III}$ are the obtained quantities analyzed in this study. Both the ECG and the respiration signals were processed using custom algorithms developed in Matlab.

The EDA signal was processed using the deconvolution method through Ledalab V3.4.9[1], a Matlab-based software package that performs event-related analysis relative to events/marker and returns various parameters of the EDA phasic—fast component, indicating the emotion induced by the stimulus—and tonic—slow component, indicating the baseline state activity (Benedek and Kaernbach, 2010a,b). Three quantitative indices were computed from the EDA signal: the average tonic activity (EDA_T) during phase III, the integrated skin conductance response (ISCR) as the time integral of the phasic activity during phase III, and the maximum value of phasic activity (PhasicMax) during phase III. The EDA_T index was normalized by subtracting its average value during the last minute of the 3-min-long baseline phase. This normalization was not necessary for the ISCR and the PhasicMax indexes, as these values are not affected by the subject's baseline.

[1] www.ledalab.de

The EEG signal was processed as explained in Vecchiato et al. (2012) to compute the attention (AI) and the pleasantness (PI) indices. Both indices were obtained from the brain signals measured above the frontal and prefrontal cortices (i.e., electrodes Fpz, AF3, F3, AF4, F4, Fz for AI, electrodes AF3, AF4, F3, F4 for PI), as the activity of neurons belonging to these areas has been correlated with attention (Klimesch, 1999; Aftanas and Golocheikine, 2001) and pleasure (Davidson, 2004; Vecchiato et al., 2011). As done in Vecchiato et al. (2012), the AI index has been reversed to have the activity of desynchronization pointing up. Therefore, an increase in the subject's attention is marked by an increase in the AI index. As concerns the PI index, the pleasure toward the product is marked by positive values. AI and PI values were normalized by subtracting their average value during the baseline and by dividing by their standard deviation during the baseline. For this purpose, we used the last minute of the 3-min-long baseline phase. After that, the normalized AI and PI values were averaged across phase III to obtain one single value for each index.

Self-Reported Measures

Self-reported emotional responses of arousal, pleasure, and situational involvement were collected through the mean of a questionnaire using validated scales after browsing each website. **Table 2** reports the expected correspondence between physiological and self-reported measures of emotions. According to prior research (Havlena and Holbrook, 1986; Kempf, 1999), we used the scale developed by Mehrabian and Russell (1974) to measure the arousal–quietness dichotomy. The arousal scale items used, listed in random order, were "excited–calm," "stimulated–relaxed," "aroused–unaroused," "sluggish–frenzied," "dull–jittery," and "sleepy–wide awake." Also, pleasure was measured with the Mehrabian and Russell (1974) scale. The specific questions for pleasure were six semantic differential items, randomly presented: "happy–unhappy," "pleased–annoyed," "satisfied–unsatisfied, "melancholic-contented," "despairing–hopeful," and "bored–relaxed." Both scale items were introduced with this instruction (Bradley and Lang, 1994): "Each line on the page contains an adjective pair which you will use to rate your feelings about the product. Some of the pairs may seem unusual, but you will probably feel more one way about one side than another. So, for each pair, place a checkmark close to the adjective which you believe describes your reaction to the picture better. The more appropriate the adjective seems, the closer you should put your checkmark to it." We measured situational involvement, a measure of the involvement and attention devoted to the product stimuli, through three 7-item Likert scales, randomly listed, asking: "I was absorbed intensely in examining the product presentation," "I concentrated fully on viewing the product presentation," and "My attention was focused on examining the product" (Webster and Ho, 1997).

RESULTS

Self-Reported Data Elaboration

We performed a reliability analysis for self-reported constructs by assessing Cronbach's alpha (**Table 3**). Results showed that our constructs are all reliable, with the pleasure construct for the functional product slightly under the commonly suggested threshold of 0.7 (Hair et al., 2012). We verified the absence of common method bias, which may be an issue when self-reported questionnaires are used to collect answers from the same participant at the same time. It represents the variance that may be attributed to the measurement method rather than the constructs that the measures represent. We employed Harman's single factor test (Podsakoff et al., 2003), which assesses the presence of common method bias by indicating whether a single latent factor offers an acceptable alternative explanation of the analysis. Results show that the single factor was explaining less than 50% of the variance; thus, we concluded that common method bias does not represent a significant threat to the study.

Manipulation and Confound Variables Check

We checked if our manipulations were successful by asking subjects to report the perceived product nature. As expected, subjects perceived the body scale as a functional product with a mean of 1.44 and the MP3 player as a hedonic product with a mean of 5.17. These means were significantly different ($t = -8.63$, $p < 0.001$), confirming the goodness of the manipulation.

TABLE 2 | Expected correspondence between physiological and self-reported measures of emotions.

Emotional response	Physiological instrument	Physiological measures (unconscious)	Self- reported instrument	Self-reported measures (conscious)
Arousal	Electrodermal activity (EDA)	EDA_T ISCR PhasicMax	Survey	Arousal scale (Mehrabian and Russell, 1974)
	Respiratory activity and cardiac activity (ECG)	HRV_{III} $PSDc/r_{III}$		
Attention/involvement	Electroencephalographic signals (EEG)	Attention Index (AI)	Survey	Situational involvement scale (SI) (Webster and Ho, 1997)
Pleasure	Electroencephalographic signals (EEG)	Pleasure Index (PI)	Survey	Pleasure scale (Mehrabian and Russell, 1974)

TABLE 3 | Reliability analysis for self-reported constructs.

Construct	Functional product		Hedonic product	
	No. of items	Cronbach's alpha	No. of items	Cronbach's alpha
Arousal	6	0.847	6	0.714
Situational involvement	3	0.743	3	0.886
Pleasure	6	0.612	6	0.742

N = 18.

Regarding product perceived diagnosticity, we confirmed that no significant differences exist between conditions with a mean of 5.17 for the functional product and a mean of 4.67 for the hedonic product ($t = 1.18$, $p = 0.244$).

Mean Comparison Between Hedonic and Functional Products

We performed a *t*-test to check if the emotions generated by functional products differ significantly with the emotions generated by hedonic products. The results indicate that there is no statistically significant difference between the mean of both physiological and self-reported emotions of arousal, pleasure, and involvement for functional and hedonic products. The mean of each variable is reported in **Figure 1**; more detailed results are reported in **Table 4**. Thus, both products generate emotions of arousal, pleasure, and involvement in consumers at the physiological as well as self-reported level.

Correlation Analysis Results

A correlation analysis was performed between the indexes obtained from the physiological data and the declared ones. As the indexes obtained from the physiological data did not follow a normal distribution, the correlation analysis was performed using a two-tailed Spearman nonparametric statistical test with a significance level set equal to 0.05. Results are reported in **Tables 5**, **6** for the functional and the hedonic product, respectively.

Correlation Analysis Between Physiological Data

For both products, the ISCR and the maximum value of phasic activity (PhasicMax) of the EDA signal show a statistically significant positive correlation, as they are both quantitative descriptors of the EDA phasic component, indicating unconscious arousal. Furthermore, both parameters show a significant positive correlation with the attention index (AI) obtained from the EEG signal. This result could suggest that the subject's attention, as quantified using information from the brain signals, increases with increasing physiological arousal, as quantified using information from the EDA signal.

Correlation Analysis Between Self-Reported and Physiological Data

The most significant results in the correlation analysis between self-reported and physiological data have been found for arousal and involvement. Specifically, for the hedonic product, the quantitative parameters obtained from the cardiac and respiratory signals show statistically significant correlations with the subjective responses. The combined effect of cardiac and respiratory activity (PSDc/r) negatively correlates with the self-reported situational involvement (SI) and with the self-reported arousal. The negative sign of the correlation is that high values of the PSDc/r identify a relaxing condition, while low values identify a stressful condition. Thus, the more engaging experience relates to high reported situational involvement and arousal, showing alignment between physiological and self-reported arousal for the hedonic product. On the contrary, for the functional product, a statistically significant correlation has been detected between physiological arousal (measured through ISCR) and self-reported arousal. As both parameters measure the engagement of the individual, the negative sign of the correlation indicates that the self-reported arousal is misaligned with the physiological arousal for the functional product.

DISCUSSION

Our results suggest that the ability to generate emotions and feelings in the consumer is not the distinguishing mark between the two product typologies. The discriminant seems, however, to lie in the connotation associated *a priori* to the offer. In our study, consumers, indeed, declared that the two products have either a functional nature or a hedonic nature. We can infer that such awareness induces to report arousal and engagement only for the products perceived to be hedonic. This is in line with recent studies, affirming that when interacting with hedonic products, consumers may devote greater attention to the emotions elicited by such interaction (Pham, 1998; Neelamegham and Jain, 1999) and are more likely to infer that their emotional responses have been provoked by the product itself (Henning et al., 2012). Hence, the same distinction between hedonic and functional products may not lie in their inherent nature but in the rationalization of their consumption. A product may be classified as functional when individuals recognize its utilitarian value but not the emotional one. Similarly, a product may be perceived as hedonic because the individual recognizes its entertainment and emotional value in the absence of perceived utilitarian value. Consumers may justify their consumption of hedonic products by embedding them with emotional values and of functional products by recognizing in them prominent utilitarian values. Such findings would confirm what has been proposed by Addis and Holbrook (2001) regarding hedonic objects: "subjectivity might be more than just a filter, but an actualizing creative force that molds the object (via a perception of it) so as to shape the resulting consumption experience (including variable emotional reactions) in ways that defy rational analysis"(Addis and Holbrook, 2001, p. 60). If the subjectivity of the consumer evaluation is the distinguishing mark, the same ambiguity in the classification of some products as either functional or hedonic would be solved. Indeed, such discriminant does not lie in the product itself but in its interpretation by the individual. For instance, coffee may be perceived as functional if the individual consumes it because of stimulation. But it can be perceived as hedonic if the consumption is driven by the sensory enjoyment of

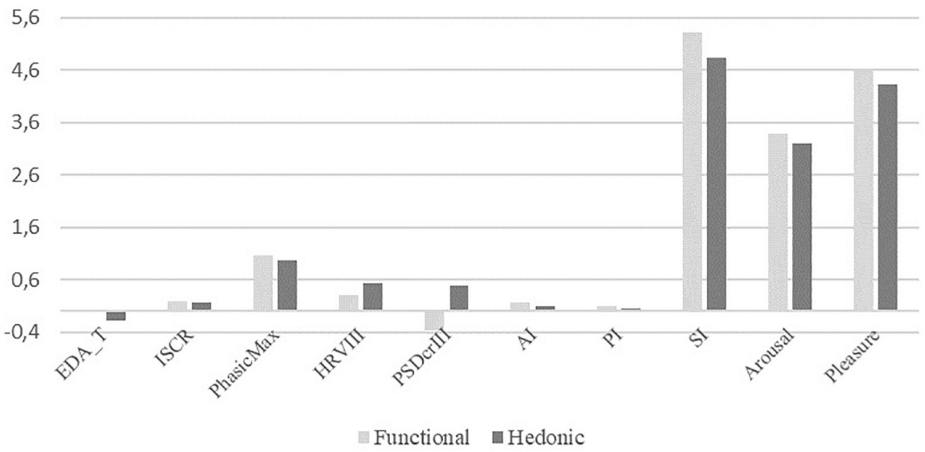

FIGURE 1 | Mean comparison between hedonic and functional products.

TABLE 4 | Mean and standard deviation of physiological and self-reported measures.

Product		***Physiological measures***							***Self-reported measures***		
		EDA_T	ISCR	PhasicMax	HRV_{III}	$PSDcr_{III}$	AI	PI	SI	Arousal	Pleasure
Functional	Mean	0.01	0.19	1.07	0.31	−0.35	0.16	0.09	5.31	3.39	4.59
	SD	0.66	0.34	1.25	0.68	1.90	0.27	0.25	0.88	1.00	0.49
Hedonic	Mean	−0.18	0.16	0.98	0.53	0.49	0.09	0.06	4.83	3.21	4.33
	SD	0.37	0.23	1.06	0.76	2.33	0.14	0.15	1.32	0.86	0.60

N =18.

coffee aroma. In the first case, post-consumption, the consumer will be more prone to recognize the energizing boost of the coffee, while in the second case its sensory attributes.

CONCLUSION

This research aims at providing theoretical and empirical evidence on the conscious and unconscious emotional responses generated by hedonic and utilitarian products. We examine the influence of the product nature (functional and hedonic) on a consumer's affective reactions of pleasure, arousal, and involvement through both physiological techniques (electroencephalography, heart rate, breath rate, and skin conductance) and self-reported instruments.

Findings show that functional and hedonic products both generate emotional responses in consumers, confirming H1a, H1b, and H1c. Neither the self-reported measures of arousal, pleasure, and involvement nor the physiological ones were showing any difference between the two product typologies, contrary to what has been argued by mainstream research (e.g., Pham, 1998; Malhotra, 2005; O'Brien and O'Brien, 2010) but in line with recent studies (Vila-López and Küster-Boluda, 2018). Further, findings of this study show that when a consumer is exposed to a functional product, the physiological emotional responses are disassociated from the self-reported ones, indicating that unconscious emotions generated by functional products may not be consciously recognized. Findings hold for arousal, pleasure, and involvement, confirming H2a, H2b, and H2c. Specifically, for arousal, we found that EDA_T and Phasic Max measures were not significantly correlated with self-reported arousal, while ISCR was negatively correlated. Similarly, physiological pleasure (PI) and physiological attention (AI) were not correlated with the respective self-reported measure of pleasure and situational involvement.

Conversely, for the hedonic product, results show a significant correlation between self-reported and physiological arousal, suggesting that unconscious arousal has been recognized at the conscious level by individuals, according to our H3a. In particular, our findings show that self-reported arousal significantly correlates with physiological arousal measured through the combined effect of cardiac and respiratory activity (PSDc/r). However, we found no correlation between self-reported and physiological pleasure and involvement, thus not confirming H3b and H3c. Such dissimilarity in findings may explain the recent controversial results of some works (e.g., Liao et al., 2016) that depict how hedonic offer may generate different outputs in terms of pleasure and arousal. Hedonic products, indeed, may generate higher pleasure than functional products only in some interaction modes (Liao et al., 2016), underlying the need of further research on this emotional reaction (Alba and Williams, 2013).

It should be noticed that, as suggested by literature (Chaudhuri, 2002; Groeppel-Klein, 2005), arousal and

TABLE 5 | Correlation analysis for the functional product.

	Emotional response	Sign of the value		EDA_T	ISCR	PhasicMax	HRV_{III}	$PSDc/r_{III}$	AI	PI	Arousal	SI	Pleasure
Physiological measures	Arousal	Positive	EDA_T	1.00	0.61*	0.58*	0.32	0.14	0.38	0.11	−0.03	−0.01	−0.13
		Positive	ISCR	–	1.00	0.94*	0.00	0.35	0.72*	0.01	−0.48*	−0.29	0.01
		Positive	PhasicMax	–	–	1.00	0.17	0.31	0.79*	0.08	−0.39	−0.24	0.04
		Positive	HRV_{III}	–	–	–	1.00	0.20	−0.03	−0.25	0.39	0.26	0.06
		Negative	$PSDc/r_{III}$	–	–	–		1.00	0.11	−0.56*	−0.07	0.02	0.06
	Attention	Positive	AI	–	–	–	–	–	1.00	−0.03	−0.15	−0.24	0.31
	Pleasure	Positive	PI	–	–	–	–	–	–	1.00	−0.27	−0.49	0.12
Self-reported measures	Arousal	Positive	Arousal	–	–	–	–	–	–	–	1.00	0.50*	0.10
	Situational Involvement	Positive	SI	–	–	–	–	–	–	–	–	1.00	−0.04
	Pleasure	Positive	Pleasure	–	–	–	–	–	–	–	–	–	1.00

Statistically significant correlations (p-value <0.05) are marked with an asterisk.

TABLE 6 | Correlation analysis for the hedonic product. (0.05) are marked with an asterisk

	Emotional response	Sign of the value		EDA_T	ISCR	PhasicMax	HRV_{III}	$PSDc/r_{III}$	AI	PI	Arousal	SI	Pleasure
Physiological measures			EDA_T	1.00	0.25	0.35	−0.04	−0.05	−0.10	−0.23	0.15	0.42	0.06
	Arousal	Positive	ISCR	–	1.00	0.92*	0.38	−0.12	0.67*	−0.04	0.14	0.00	0.45
		Positive	PhasicMax	–	–	1.00	0.31	−0.18	0.66*	−0.15	0.11	0.04	0.45
		Positive	HRV_{III}	–	–	–	1.00	−0.72*	0.46	−0.10	0.36	0.42	0.27
		Positive	$PSDc/rV_{III}$	–	–	–		1.00	−0.27	−0.07	−0.48*	−0.54*	−0.41
	Attention	Negative	AI	–	–	–	–	–	1.00	0.17	−0.07	−0.21	0.36
	Pleasure	Positive	PI	–	–	–	–	–	–	1.00	−0.02	−0.11	0.25
	Arousal	Positive	Arousal	–	–	–	–	–	–	–	1.00	0.55*	0.15
	Situational Involvement	Positive	Pleasure	–	–	–	–	–	–	–	–	1.00	0.37
	Pleasure	Positive	SI	–	–	–	–	–	–	–		–	0.37

Statistically significant correlations (p-value < 0.05) are marked with an asterisk.

involvement show to be strongly connected, being self-reported measures of arousal and situational involvement positively correlated for both the hedonic and the functional products. The same holds for physiological measures, where the subject's attention (AI), as quantified using information from the brain signals, significantly increases with increased activation of the sympathetic nervous system, as quantified using information from the EDA signal (ISCR and PhasicMax). Interestingly, for the hedonic consumption scenario, such connection is evident in the correlation between self-reported and physiological measures of arousal. Here physiological arousal measured through PSDc/r correlated with both self-reported arousal and self-reported involvement, providing further confirmation to H3a. Thus, our findings provide support to the assumption that, even when arousal is elicited similarly in both hedonic and utilitarian consumption, individuals are more likely to consciously recognize their emotional responses for hedonic consumption only.

RESEARCH AND MANAGERIAL IMPLICATIONS

The study contributes to research in three main directions. First of all, it warrants new findings to research on functional and hedonic consumption by depicting the different emotional reactions that consumers show while interacting with such product typologies. Despite numerous writers suggesting that hedonic, but not functional, products provide emotional experiences to individuals, we determine that functional products elicit emotional feelings in the consumer in the same extent as hedonic products.

Secondly, results show that functional products elicit unconscious emotions in consumers that, however, are not consciously recognized. Conversely, unconscious arousal and involvement generated through hedonic consumption are consciously recognized by consumers and thus can be reported. This finding may explain the lack of emotional reactions toward functional products found in prior research. The self-reported methods used in all prior studies (e.g., Kempf, 1999) may have been inadequate to detect the emotional reactions toward functional products. As we show in this work, even if consumers feel aroused and engaged, they can report it only for the hedonic product and not for functional ones. Thus, we propose an alternative explanation to the apparent lack of affect-rich experiences elicited by functional products that research has neglected. Results stress the need to reconsider emotional reactions for utilitarian products as well. From a managerial perspective, this provides new weight to emotional communication strategies, as marketers may evaluate the opportunity to convey emotional and visceral messages to promote utilitarian products above hedonic ones.

This is especially relevant in light of the aforementioned role of subjective evaluations of the product nature, more than objective classification, for which marketing communication plays a major role.

This leads to the third contribution of this work, which is methodological. The study, indeed, shows that traditional instruments, such as surveys, and physiological analyses provide complementary information about the feelings and emotions generated by products. The former detect the conscious emotions for which the consumer is aware and thus can report. The latter provide information about the unconscious emotional reactions that research acknowledges as powerful drivers of decision-making (e.g., Kihlstrom et al., 2000; Ivonin et al., 2013). Thus, this research provides an initial step toward using physiological responses to deeply evaluate a consumer's experience with new products. In line with such results, we suggest that marketers and product managers should adopt physiological methods in combination with self-reported ones to properly assess the experience evoked by their products both earlier along the new product development process and at the end of the process to develop marketing communication accordingly.

LIMITATIONS AND FUTURE RESEARCH

The findings of this work are expected to be particularly robust due to the deployment of an experimental study in a laboratory setting using two different assessment methods: self-reported measures and physiological ones. Moreover, several physiological tools (electroencephalography, electrocardiogram, respiratory activity, and EDA) have been used to assess the emotional reactions of consumers. However, the choice of the laboratory experiment as the empirical setting, despite the fact that it provides higher internal validity being not affected by external influences, is lower in external validity. The artificiality of the setting, indeed, may have produced unnatural behaviors or reactions in consumers that do not reflect real-life behaviors. Thus, it limits generalizability to real environments in which consumers interact with products.

Additionally, future research is needed to replicate and extend our findings. In this work, we tested two electronic devices that, despite having been validated as representative of the hedonic and functional typologies (Bettiga et al., 2017a), pertain to a specific product category. Thus, we suggest replicating our study on different product categories to understand if differences in emotional reactions may occur. It would be particularly interesting to deploy such a study on product categories that are balanced in terms of functional and hedonic features to explore the role of consumer subjective evaluation in their classification and their subsequent emotional responses toward consumption. Similarly, the empirical test has been conducted on consumers of a restricted age range. Even if a reduced age range is necessary for physiological experiments, to assure the comparability of data collected, a replication of such empirical study on other consumer segments may provide additional information on the consumer's emotional patterns.

Finally, we measured emotions through physiological measures and self-reported scales, revealing that both measures are necessary and showing that conscious and unconscious emotions are, in some instances, not aligned, in others positively correlated. However, it would be interesting if future studies could investigate the extent of such relationships and additional factors that may affect them.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. There are several reasons why an explicit approval by an Ethics Committee was not necessary: the participants are adults, the research does not involve vulnerable subjects, the participation in the study is voluntary, it is a minimal risk research, all data collected is treated anonymously. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

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

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Transparent Windows on Food Packaging Do Not Always Capture Attention and Increase Purchase Intention

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Transparent windows on food packaging can effectively highlight the actual food inside. The present study examined whether food packaging with transparent windows (relative to packaging with food- and non-food graphic windows in the same position and of the same size) has more advantages in capturing consumer attention and determining consumers' willingness to purchase. In this study, college students were asked to evaluate prepackaged foods presented on a computer screen, and their eye movements were recorded. The results showed salience effects for both packaging with transparent and food-graphic windows, which were also regulated by food category. Both transparent and graphic packaging gained more viewing time than the non-food graphic baseline condition for all the three selected products (i.e., nuts, preserved fruits, and instant cereals). However, no significant difference was found between transparent and graphic window conditions. For preserved fruits, time to first fixations was shorter in transparent packaging than other conditions. For nuts, the willingness to purchase was higher in both transparent and graphic conditions than the baseline condition, while the packaging attractiveness played a key role in mediating consumers' willingness to purchase. The implications for stakeholders and future research directions are discussed.

Keywords: transparent packaging, willingness to purchase, attractiveness, eye tracking, visual attention

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INTRODUCTION

When consumers stand in front of the shelves in a supermarket, food packaging attracts their attention, and plays an important role in shaping consumers' food choice behavior. Food packaging not only protects food and extends the shelf life of food products, but also conveys the information like product attributes, price, and promotional messages (Hawkes, 2010). For customers, food packaging is a direct source to obtain food-related information such as the food category, brand, manufacturer, and expiration date, which form the basis of food decision-making. With the increase in market competition, food manufacturers are paying increasing attention to packaging design to maintain regular customers and attract new customers (Silayoi and Speece, 2007; Kuvykaite and Navickiene, 2009; Estiri et al., 2010; Simmonds and Spence, 2019). Opaque packaging is widely used in food packaging, especially packaging with product images. Imagery can capture consumer attention, provide information about the product and

brand, and increase overall interest in the product, which promotes consumers' purchase intentions (Simmonds and Spence, 2019). One emerging trend of packaging design involves transparent elements in food packaging. Packaging with transparent elements shows consumers the most authentic appearance of the food inside the packaging (Fernqvist et al., 2015). Compared with opaque packaging (with or without a product image), what superiority do packages with transparent elements have? What's the role of transparent elements in shaping consumers' feeling? How does it influence consumers' purchase behavior? These questions have been partially answered by several previous studies.

In the review of visual factors influencing consumers' visual hunger, Spence et al. (2016) pointed out that the visibility of attractive foods, or viewing pictures of desirable food, increases our visual hunger. This opinion is consistent with the "salience effect" hypothesis proposed by Deng and Srinivasan (2013). According to this hypothesis, the transparent packaging makes the food inside more conspicuous, which increases food consumption. However, such effects were modulated by food size and appearance. Deng and Srinivasan (2013) used foods like candies and cookies as experimental materials and examined the effects of food size, appearance, and packaging transparency on food consumption. They found that the salience effect was most apparent when small and visually attractive foods were presented with transparent packaging. However, the "monitoring effect," which refers to transparent packaging enabling consumers to monitor their consumption better and thus eat less, was apparent when participants were shown large, unattractive foods. The researchers also found that seeing vegetables in a transparent package decreased the consumption of vegetables, which might be because vegetables were not regarded as tasty or attractive.

In order to systematically explore the relationship between packaging transparency and purchase intention, Simmonds et al. (2018b) classified packaging transparency into three categories: transparent with a visible product object ("window"), completely opaque with a product image ("graphic"), and completely opaque with no product image ("blank"). The researchers examined how packaging transparency affected consumer attitude, like expected tastiness, expected food quality, and expected freshness, as well as purchase intention. The materials included four kinds of food packaging pictures, used on cereal, boxed chocolates, dried pasta, and fresh fish. They found that participants preferred to buy foods with transparent packaging rather than opaque packaging. Participants also perceived food in transparent packaging to be fresher, tastier, and more innovative. The data suggest that seeing the food directly through the transparent window may induce the salience effect, resulting in higher hunger levels and food demand, leading to higher purchase intention (see also Billeter et al., 2012).

However, transparent packaging does not necessarily trigger positive feelings. Chandran et al. (2009) examined how packaging transparency affected the perceptions of food quality, product trust, and purchase intentions for both familiar and unfamiliar brands. The results showed that participants judged an unfamiliar product to be of higher quality and trustworthiness when it was in transparent packaging and preferred to pay more for it. In contrast, participants regarded familiar products with transparent packaging as being of lower quality, though participants did not show more distrust than toward the products with opaque packaging. Therefore, both product trust and product familiarity modulated the perception of food quality, which impacted purchase intention. Moreover, Riley et al. (2015) stated that transparent windows decrease, rather than increase, the perceived healthiness of the tested products, such as coffee, carrot soup, and carrot baby food. These sensory evaluations suggest that transparent packaging does not always induce salience effects.

Vilnai-Yavetz and Koren (2013) further examined how extra variables like perceived ease of use, aesthetics, and symbolism influence the evaluation of, and purchase intention toward, foods with transparent packaging. The researchers asked the participants to purchase mixed boiled vegetable meals with either an opaque wrapper showing a picture of the food, or a transparent plastic cover revealing the food inside. The product with the transparent cover had 30% lower sales than the product with opaque products. The evaluation tasks showed that consumers had more interest in buying products with opaque packaging. The transparent packaging evoked higher perceived ease of use (e.g., the package looks easier to open and seems to heat up easily) and lower perceived aesthetics (e.g., the package is unattractive) and symbolism (e.g., food quality does not look very good) than opaque packaging. Therefore, perceived aesthetics and symbolism also modulate the salience effect of packaging transparency. In the case of vegetables or vegetable meals, transparent packaging appears to have little superiority over opaque packaging in terms of food choice.

In sum, previous studies suggest that transparent packaging induces salience effects, such as triggering high levels of hunger and a higher willingness to purchase. However, transparent packaging may decrease several subjective feelings such as product quality, trustworthiness, aesthetics, and healthiness, and these effects are constrained by product categories and product familiarity (see the review by Simmonds and Spence, 2017). Therefore, more kinds of products should be tested to extend the knowledge about the role of packaging transparency. Additionally, the salience effect hypothesis predicts that transparent packaging will attract consumer attention, but the prediction is based on the literature of food-related attention bias studies using probe detection tasks. Eye-tracking approaches have not been used to test whether transparent packaging attracts consumer attention, and how this attraction modulates purchase behaviors. Therefore, the more objective method of eye tracking should be used to monitor consumer attention when evaluating food products with different packaging transparencies.

Currently, as technology develops to explore consumers' visual processing behaviors in the real world, the eye-tracking approach is increasingly applied in the field of consumer behavior and marketing (Wedel and Pieters, 2007) to explore the impact of various packaging features on consumers' visual attention and food choices (Piqueras-Fiszman et al., 2013; Bialkova et al., 2014, 2020; Husic-Mehmedovic et al., 2017; Fenko et al., 2018; García-Madariaga et al., 2019; Peschel et al., 2019; Ma and Zhuang, 2020). For instance, Piqueras-Fiszman et al. (2013) combined eye tracking

and word association to assess novel packaging solutions. They found that certain elements of the product packaging attracted visual attention. In particular, consumers paid more attention to the photo on the package than the text in the same place. Consumers also preferred to buy the product with a photo rather than a message text on the packaging. According to the salience effect hypothesis (Deng and Srinivasan, 2013), transparent elements in packaging can attract consumer attention, subsequently increase their willingness to purchase.

In the literature about the relationship between attention and choice (Orquin and Mueller Loose, 2013; Van Loo et al., 2018), attention is a primary condition for the choice of corresponding objects. Some non-food studies showed that long processing time could predict preference for that stimulus (Maughan et al., 2007; Armel et al., 2008), and fixation time measures showed a similar trend when eye-tracking approaches were used (Gidlöf et al., 2017). In simulated shopping situations, the food product fixated on most had the highest probability of being chosen (Bialkova et al., 2014). However, the relationship between viewing time and preference formation may depend on experimental tasks. Wolf et al. (2018) found that longer viewing was associated with a higher likelihood of a positive evaluation in the self-paced exclusive evaluation (i.e., purchase intention "No" or "Yes"), but not in the self-paced non-exclusive evaluation (i.e., a Likert scale using 1–5 to indicate the attitude from dislike to like). Therefore, it is unclear whether more viewing time on transparent packaging leads to higher purchase intention. The present study not only tested the salience hypothesis for transparent packaging by using an objective eye-tracking approach, but also examined the relationship between attention and perceptual evaluation.

Following the study performed by Simmonds et al. (2018b), we used three packaging types: packaging with a transparent window ("transparent"), completely opaque packaging with a food image ("graphic"), and completely opaque packaging with a non-food image ("baseline"). This baseline is different from the blank condition used by Simmonds et al. (2018b), in that this study includes a match-sized non-food object to balance the visual differences of three packaging types. This control variable would make sure the differences among the three packaging types were caused by packaging types, rather than visual differences. The materials included packaging of the following three kinds of foods: nuts, preserved fruits, and instant cereals (see detailed information in the "Material" section). In the process of viewing food packaging, we not only recorded consumers' eye movements, but also recorded their willingness to purchase the corresponding products, and the attractiveness evaluation of the corresponding packaging. Based on the following two important characteristics of the salience effect hypothesis (Deng and Srinivasan, 2013): (1) Salient food packaging elements can effectively attract the attention of consumers; (2) Attention attracted by salient elements will improve consumers' willingness to purchase, two hypotheses were proposed:

H1: Transparent, rather than graphic, packaging can attract more attention (i.e., longer total time, larger number of fixations, and shorter time to first fixation of the transparent window) than packaging in the baseline condition.

H2: The eye movement measures reflecting salience effects are related to a willingness to purchase.

However, according to previous studies (Deng and Srinivasan, 2013; Vilnai-Yavetz and Koren, 2013), if product category regulated salience effects, the eye movement measures would show different results for different product categories. Using the eye-tracking approach, we expect the present study to provide insights on the role of transparent packaging and thus contribute to knowledge of food packaging design.

MATERIALS AND METHODS

Participants

A power calculation performed using the G*power software suggests that at least 52 subjects per condition are needed to detect a medium effect size (most of effect sizes for WTP were larger than 0.3 in Simmonds et al., 2018b) of $d = 0.8$ with $\alpha = 0.05$ for a one-way ANOVA analysis. In addition, a recent review on eye-tracking studies of nutrition label processing indicated that a small and convenient sampling could provide reliable findings on consumer behavior (Ma and Zhuang, 2020). In the review, there were 33% studies with sample size less than 60 participants and the smallest sample size was only 10 participants (Bialkova and van Trijp, 2011). Therefore, a convenient sample of 55 college students (30 females, ages between 18 and 21; 25 males, aged between 18 and 21) from Shaanxi Normal University in Xi 'an, China, was paid to participate in the experiment. The participants had no color blindness, color weakness, or history of mental illness. They had normal or corrected-to-normal vision. Ten students were unable to conduct the formal experiment due to calibration or other eye-tracking problems. Thus, 45 participants (25 females and 20 males) were kept for final data analyses.

Materials

A pilot study was performed before creating the experimental materials. The pilot study investigated the popularity and category of products with transparent packaging in markets in Xi'an. Three off-line supermarkets (Vanguard, Wal-Mart, Yonghui) were visited to survey the transparent materials used to package food products. The survey found that the packaging materials of prepackaged food on the shelves were divided into three categories: box, bag, and can. Of the 170 food brands surveyed, 70.6% of them used bag packaging, 17.1% packaged their products in cans, and 12.3% of them used boxes. Since bags are the most commonly used packaging in prepackaged foods, all food packaging pictures in this study were designed on bags. The pilot study also showed that transparent packaging was frequently used for biscuits, cereals, grain products, potatoes and puffed grain foods, candy products, preserved fruits and other fruit products, stir-fried food, nut products, and frozen foods (see **Figure 1**). Moreover, our online survey based on a large e-commerce platform in China showed that nut products, preserved fruits, and instant cereals were the three most

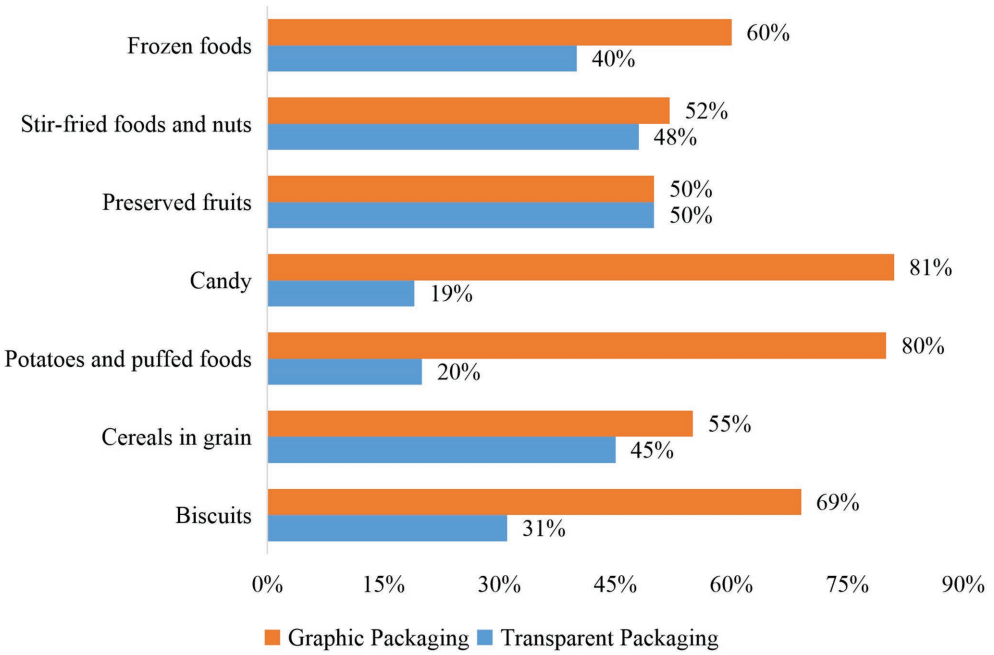

FIGURE 1 | The use of transparent and graphic packaging in different food categories. Proportion of graphic or transparent packaging in one food category = Number of graphic or transparent packaging for the observed food category/Total number of graphic and transparent packaging for that observed food category.

popular foods for sale. Thus, these three categories were selected to create the experimental materials.

Each product category contains nine different foods, forming a total of 27 food products included in the current study. Adobe Photoshop CS6 software was used to create pictures of experimental food packaging. Each packaging picture contains elements such as the trademark, food name, a picture or transparent window, certification mark, and food net content. Each food was packaged in three different ways: transparent window packaging (*transparent*), graphic window packaging (*graphic*), and baseline window packaging (*baseline*). To avoid the influence of food trademarks on the subjects, all foods were named with a nonexistent brand that the subjects had never seen before (Simmonds et al., 2018b). In order to reduce the visual differences of the three versions of packaging, we matched the position and size of food trademarks and windows, which were also based on actual products in supermarkets to increase ecological validity. Finally, 81 food images were created as stimuli in the formal experiment (see **Figure 2** for an illustration of experimental stimuli).

Apparatus

The stimuli were presented on a 24-inch LCD monitor (ASUS VG248QE) with a resolution of 1920 × 1080 pixels and a refresh rate of 144 Hz. The distance between the participants' eyes and the screen was 62 cm. Each packaging image occupied about 24 cm vertically and 20 cm horizontally on the screen. Participants' eye movements were recorded by an EyeLink 1000 Plus (SR Research Ltd., Ontario, Canada) eye tracker with a sample rate of 1,000 Hz. A chin rest was used to reduce head movements. Since both eyes fixate on the same spot, recording one eye is sufficient. Experimental data were collected and processed by the Experiment Builder and Data Viewer software.

Procedure

After arriving at the lab, participants were asked to rate their hunger levels (1 = not hungry at all, 7 = very hungry) and their desire to eat (1 = not strong at all, 7 = very strong) using a seven-point Likert scale. If a participant's score was higher than 4, they were asked to eat snacks that were unrelated to the experimental stimuli. When asked again, the participant rated their hunger and desire to eat as less than 4 after eating the snacks. Single factor Latin square experimental design was adopted for the three package types (i.e., transparent window packaging, graphic window packaging, and baseline window packaging). There were three sets of trials, and each set contained 27 trials, which included different food packaging. Participants were randomly assigned to each set.

During the experimental stage, the researcher briefly introduced the overall procedure and experimental equipment to the participants, and then carried out a five-point calibration. After successful calibration, participants finished three practice trials to familiarize the experimental procedure. None of the stimuli used in the practice sessions appeared in the formal experiment. The participants then performed the formal experiment with 27 trials (see **Figure 3** for a demonstration). After participants focused on a fixation cross for 300 ms, the

FIGURE 2 | Examples of stimuli used in experiment. First column: transparent window packaging; second column: graphic window packaging; last column: baseline window packaging. Top row: nuts; middle row: preserved fruits; bottom row: instant cereals.

FIGURE 3 | A brief demonstration of experiment procedure.

packaging images appeared, and participants were asked to view the images freely, pressing the space bar when they were ready to proceed to the next stage. Participants were then asked to estimate their willingness to purchase the product (i.e., *How likely would you be to buy this food, assuming it was available and at a reasonable price?*) and the product's visual attractiveness (i.e., *How attractive is the packaging to you?*) of each packaging image, using seven-point Likert scales.

Data Analysis

The main region of interest (ROI) is the window region for each type of packaging. Dependent variables included two perceptual measures (willingness to purchase and packaging attractiveness), and the following three eye movement measures for each ROI. *Time to first fixation* (TTFF; i.e., latent time to first fixate an interest area Ma and Zhuang, 2020) was selected as one of the main indicators of attention capture by salient features. The shorter the time to the first fixation was, the more the salience effect was apparent for the observed area of interest. We also selected two most commonly used eye movement measures: *total time* (TT; i.e., the sum of the duration across all fixations that fall in the current interest area) and *number of fixations* (NF; i.e., total number of fixations falling in the interest area) to reveal the total attention interest in the corresponding region (Wedel and Pieters, 2007; Holmqvist et al., 2011). The extreme value (±2.5 *SD*) of the concerned eye movement measures was excluded. More than 97.6% of data were kept for final analyses. ANOVA was used to analyze the variance of all dependent variables, and Bonferroni corrections were used for paired comparisons. Spearman's correlation coefficient was used to test the correlation between the eye movement indexes and behavior indexes with SPSS 22.0.

RESULTS

Eye-Tracking Measures

Time to First Fixation

Detailed eye movement measures and the results of paired comparisons are presented in **Table 1**. Time to first fixation did not show significant main effects for nuts, $F(2, 42) = 0.40$, $p = 0.675$, and instant cereals, $F(2, 42) = 1.29$, $p = 0.286$. However, for preserved fruits, there were significant differences among different package types, $F(2, 42) = 4.24$, $p = 0.021$. The times to first fixation on the window region in the *"transparent"* condition were significantly shorter than the *"baseline"* condition. This result meant that the transparent window in preserved fruit packaging could capture participants' attention more quickly.

Total Time

The main effects of package type for total time were significant for nuts, $F(2, 42) = 15.97$, $p < 0.001$, preserved fruits, $F(2, 42) = 20.71$, $p < 0.001$, and instant cereals, $F(2, 42) = 11.39$, $p < 0.001$. Paired comparison showed that for the three food categories, the total time in the *"transparent"* conditions (*ps* < 0.001) and *"graphic"* conditions (*ps* < 0.014) were significantly longer than that in the *"baseline"* condition. There was no significant difference between the *"transparent"* and *"graphic"* conditions, *ps* > 0.223.

Number of Fixations

The number of fixations also showed significant main effects for nuts, $F(2, 42) = 14.62$, $p < 0.001$, preserved fruits, $F(2, 42) = 22.21$, $p < 0.001$, and instant cereals, $F(2, 42) = 8.75$, $p = 0.001$. Paired comparisons showed that number of fixations in the *"transparent"* conditions (*ps* < 0.001) and *"graphic"* conditions (nuts: $p = 0.037$, preserved fruits, $p < 0.001$, and instant cereals: $p = 0.062$) were significantly more than the *"baseline"* conditions. For nuts, the number of fixations in the *"transparent"* condition was significantly more than the *"graphic"* condition ($p = 0.024$). However, there were no significant differences between the *"transparent"* and *"graphic"* conditions in the other two kinds of foods.

Perceptual Measures

Willingness to Purchase

Descriptive assessment data and the results of paired comparisons are presented in **Table 2**. For nuts, the main effect of package type was significant, $F(2, 42) = 3.95$, $p = 0.027$. Paired comparison revealed that the willingness to purchase in the *"transparent"* condition was significantly higher than the *"baseline"* condition ($p = 0.048$). Though the main effects of package type for the preserved fruits and instant cereals were insignificant, descriptive statistics showed that the participants were more willing to buy the products with graphic or transparent windows.

TABLE 1 | Eye movement measures for the three packaging types in each food category.

		Time to first fixation (ms)		Total time (ms)		Number of fixations	
Food	**Packaging**	***M***	***SD***	***M***	***SD***	***M***	***SD***
Nuts	Transparent	5,052[a]	2,514	2,904[a]	1,306	10.6[a]	4.5
	Graphic	4,915[a]	2,590	2,250[a]	939	7.3[b]	2.7
	Baseline	4,189[a]	3,374	922[b]	532	4.2[c]	2.1
Preserved fruits	Transparent	4,229[b]	2,223	2,007[a]	979	6.9[a]	2.8
	Graphic	5,761[a, b]	2,867	2,335[a]	1,061	8.8[a]	3.9
	Baseline	7,259[a]	3,353	458[b]	314	2.1[b]	1.2
Instant cereals	Transparent	6,282[a]	5,781	2,492[a]	1,177	8.3[a]	3.8
	Graphic	4,420[a]	2,171	1,894[a]	1,102	6.4[a, b]	3.1
	Baseline	7,096[a]	5,254	849[b]	367	3.8[b]	1.6

For a specific eye movement measure, mean values within each food category with different superscript letters are significantly different according to the results of paired comparison with Bonferroni correction (p < 0.05).

Packaging Attractiveness

The main effects of package type on packaging attractiveness were significant for nuts, $F(2, 42) = 6.85$, $p = 0.003$, preserved fruits, $F(2, 42) = 4.53$, $p = 0.017$, and instant cereals, $F(2, 42) = 5.80$, $p = 0.006$. For nuts and instant cereals, both the *"transparent"* stimuli ($ps < 0.027$) and *"graphic"* stimuli ($ps < 0.010$) were rated as more attractive than the *"baseline"* stimuli, while there were no differences between the *"transparent"* and *"graphic"* conditions ($ps > 0.155$). For preserved fruits, only the *"graphic"* stimuli were rated as more attractive than the *"baseline"* stimuli ($p = 0.016$). Descriptive statistics also revealed that the graphic window packaging was the most attractive one for all the three kinds of food category.

Correlation Between Eye Movements and Perceptual Measures

Correlations between eye movements and perceptual measures in different packaging types under each food category were analyzed though the Spearman's correlation (see **Table 3**). For preserved fruits, eye movement measures such as *total time* and *number of fixations* were significantly positively correlated with the scores of packaging attractiveness and willingness to purchase, but the other correlations were insignificant. There were also significantly positive correlations between the scores of packaging attractiveness and willingness to purchase (nuts: $r = 0.88$, $p < 0.001$; preserved fruits: $r = 0.83$, $p < 0.001$; and instant cereals: $r = 0.94$, $p < 0.001$). Therefore, packaging attractiveness, instead of eye movement measuring, is more appropriate to predict willingness to purchase.

TABLE 2 | Perceptual measures for the three packaging types in each food category.

		Willingness to purchase		Packaging attractiveness	
Food	**Packaging**	***M***	***SD***	***M***	***SD***
Nuts	Transparent	4.82[a]	0.90	4.43[a]	0.80
	Graphic	4.76[a, b]	0.89	4.71[a]	0.92
	Baseline	3.93[b]	1.11	3.42[b]	1.24
Preserved fruits	Transparent	4.73[a]	0.86	4.26[a, b]	1.06
	Graphic	4.93[a]	0.85	5.00[a]	0.87
	Baseline	4.20[a]	1.06	3.92[b]	1.07
Instant cereals	Transparent	4.08[a]	1.43	3.90[a]	1.36
	Graphic	4.32[a]	1.10	4.05[a]	1.05
	Baseline	3.34[a]	0.74	2.77[b]	0.93

Mean values within each food category with different superscript letters are significantly different according to results of paired comparison with Bonferroni correction ($p < 0.05$).

DISCUSSION

The present study used an objective eye-tracking approach to examine how packaging transparency and product category affected consumer attention and purchase behavior. The eye-tracking method overcame the limitation of the subjective evaluation method in assessing a product's attraction and consumers' attention toward it (Deng and Srinivasan, 2013; Simmonds et al., 2018a,b, 2019), thus providing more direct evidence to test the salience effect hypothesis. The results of eye-tracking data showed that the salience effect was modulated by product category. Additionally, the results showed that, out of the three product categories tested, transparent window packaging attracted consumer attention most quickly for preserved fruit. In general, transparent window packaging and graphic window packaging capture consumers' attention better, resulting in longer total time and a larger number of fixations than the baseline condition. Furthermore, the perceptual measures revealed that the willingness to purchase was strongly related to the attractiveness of food packaging for all three food categories, but only had a significant correlation with fixation measures for preserved fruit. Based on these findings, we will discuss the relationship between packaging design and the salience effect, as well as the factors influencing consumers' purchase intention.

Salience Potentially Unique to Transparent Window Packaging

In previous studies, according to the salience effect hypothesis, researchers proposed that packaging with transparent elements would always stand out to consumers compared with opaque packaging, and attracted consumers to eat more, or promoted their purchase behavior (Deng and Srinivasan, 2013; Simmonds et al., 2018b). However, using the eye-tracking approach is necessary to definitively ascertain if packaging with transparent elements really captures consumer attention. Generally, consumers tend to look at the top half of a novel product's packaging (Juravle et al., 2015). However, even a potentially preset scanpath does not influence the comparison of packaging attraction for

TABLE 3 | Spearman's correlation coefficients between eye movements and perceptual measures.

	Willingness to purchase			Packaging attractiveness		
	Nuts	**Preserved fruits**	**Instant cereals**	**Nuts**	**Preserved fruits**	**Instant cereals**
Time to first fixation	0.13	0.25	0.05	0.13	0.12	0.07
Total time	−0.03	0.31*	0.04	0.03	0.41**	0.14
Number of fixations	−0.05	0.33*	0.01	0.00	0.43**	0.10

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

different packaging types in the current within-subject design experiment.

Time to first fixation was used as one of the main indicators to investigate the salience effect in this study. The data showed that only preserved fruits had a significant main effect and whose transparent window packaging successfully attracted consumer attention. For nuts and instant cereals, however, even the descriptive statistics did not show a shorter time to first fixation for product packaging with a transparent window. These data were partially inconsistent with the prediction of the salience effect hypothesis (Spence et al., 2016), which might be caused by the food categories we selected. The foods in this study were selected according to the utilization rate of transparent packaging and food sales volume, which meant that participants had corresponding purchasing experience or a personal preference for these foods. By involving personal expectations, their gaze behaviors were not only affected by the stimulus' physical characteristics (bottom-up) but also by the participants' subjective expectations (top-down). Therefore, the early-stage measure of *time to first fixation* may reflect the interaction between the participants' bottom-up and top-down processing of the packaging pictures.

The later-stage measures, such as *total time* and *number of fixations*, always reflected sustained attention. A number of studies have shown that visually salient stimulus not only captured participants' attention quickly but also retained longer processing time (Shimojo et al., 2003; Bialkova and van Trijp, 2011; Milosavljevic et al., 2012; Orquin and Mueller Loose, 2013). In this study, *total time* and *number of fixations* of the transparent and graphic window packaging of all three food categories were higher than the baseline window packaging. Also, there was no statistically significant difference between the transparent and graphic window packaging in any food category, except the number of fixations in nuts packaging. These results indicate that showing food information, whether the actual food, or a picture of it, can stand out and retain consumers' attention, thus H1 is partially verified. Previous studies emphasized the salience effect of transparent packaging but ignored the effects of graphic packaging, which may be related to experimental materials. Deng and Srinivasan (2013) did not involve the category of graphic window packaging in their study. Simmonds et al. (2018b) included graphic window packaging, but they only selected one product out of each food category, thus the generalizability of the transparent packaging effect needs to be further examined. The materials used in the present study consist of nine types of food for each food category, which can provide higher ecological and statistical validity. The data suggest that salience is not limited to transparent window packaging because food-related graphic window packaging can also capture consumers' attention.

Attractiveness Influences the Willingness to Purchase

Shimojo et al. (2003) proposed a dual-contribution model in which cognitive assessment systems and orienting behavior structures simultaneously influence people's preferential decision-making behavior, through facial attractiveness decision experiments. When a stimulus attracts our attention and produces a preference to gaze it, the preference will lead to more exposure to the stimulus, which creates an increased preference. Preference in turn increases our gaze behavior, so as to continuously strengthen our perception of stimulus to influence our decisions (Shimojo et al., 2003; Simion and Shimojo, 2006). This model provides a plausible explanation for the mechanism underlying the transparent window salience effect. The explanation is that when consumers are exposed to the food through a transparent window, the food captures our attention, which seemly produces a gaze preference for the transparent window packaging compared with other packaging. This preference may make consumers pay more attention to transparent window packaging, and the increase in gaze time translates into a higher preference, which could lead to increased willingness to purchase the food in that packaging. Therefore, *total time* and *number of fixations* should have a significant positive correlation with the willingness to purchase. However, the results of this study show that only *total time* and *number of fixations* of preserved fruits were significantly and positively correlated with purchase intention. For nuts and instant cereals, none of the correlations between fixation patterns and willingness to purchase were statistically significant. These results were *inconsistent* with H2. This means that long gaze duration does not necessarily lead to a final purchase decision (see also Balcombe et al., 2017; Wolf et al., 2019). Wolf et al. (2019) found that the relationship between gaze time and three options [i.e., the exclusive evaluation task contains rejection, deferment, and inclusion; the non-exclusive evaluation task contains 1 ("not at all"), 2 (neutral), and 3 ("very much")] from participants who presented an inverted U-shaped trend. Therefore, the gaze may not necessarily lead to more liking but contribute to the evaluative processing by integrating extra information. As Wolf et al. (2019) suggested, the prolonged viewing time for the middle category may reflect doubt or uncertainty during the evaluative processing, potentially with an increased effort of information integration before reaching a conclusion.

In this study, there was a significant positive correlation between perceived packaging attractiveness and a willingness to purchase. After the formal experiment, when participants were asked why they did or did not want to buy the product, almost all of them mentioned their impressions of the packaging. We speculate that consumers' willingness to purchase is likely to be affected by the aesthetic perception of packaging. The correlation analyses also revealed that there was a significant positive correlation between packaging attractiveness and willingness to purchase. Simmonds et al. (2018b) proposed that the packaging attractiveness was a necessary premise of supporting the salience effect of transparent window packaging. The authors argued that transparent window packaging could enhance consumers' purchase intention by highlighting the food inside, and attractive transparent window packaging can make this effect more notable. However, the results of the current study suggest that packaging attractiveness appears to work at a more general level. Showing the food in a concrete form (i.e., presenting actual foods through transparent windows

or displaying food images on graphic windows) to consumers can indeed attract consumers' attention effectively. However, the attractiveness of food packaging most significantly promotes consumers' willingness to purchase the product.

Salience of Different Food Categories

Combined with eye movement and perceptual measures, this study further revealed that product category regulated the effect of packaging type on consumer attention. That means consumers may have different gaze patterns for different products. For nuts, most are shelled, and the difference between the actual food inside the packaging and the food image is slight. The data showed that there were no statistical differences between *"transparent"* and *"graphic"* stimuli for all the measures except for *number of fixations*, which suggests that both transparent and graphic window packaging have similar salience effects for nuts. Therefore, transparent window packaging and graphic window packaging can efficiently capture consumers' attention and increase product attractiveness.

Participants preferred the graphic window packaging on preserved fruits more than the transparent window packaging according to the perceptual results, although the preference was slight. In combination with participants' feedback after the experiment, we found that most types of preserved fruits in this study were often coated in sugar or honey. These sticky coatings would smear against the inner transparent window of the packaging and reduce participants' appetite. Therefore, when participants saw the sugar- or honey-coated preserved fruits through the transparent window, they would avoid the package. Most preserved fruits are sticky or frosted, and thus graphic window packaging is more suitable to attract consumers to these products.

In their study, Simmonds et al. (2018b) also inspected instant cereals. Although the pictures of the cereal packaging in this study were similar to their experimental materials, there are several differences. Only one food for each food category was used in their study, and the baseline was a blank condition. In this study, nine types of foods for each category were selected, and the baseline was size-matched non-food graphic objects. Moreover, Simmonds et al. (2018b) asked participants to sort different packaging types presented at the same time according to participants' judgments. This method was more likely to induce significant differences between the transparent and graphic conditions than the one-by-one estimation method used in the present study. These differences may contribute to the different conclusion they arrived at, where the salience effect only applied to transparent conditions. The present study revealed salience effects for both transparent and graphic conditions.

Limitations and Future Directions

The present study has several limitations. First, all conclusions of this study are based on Chinese college students and packaging types used in the Chinese market. Future research could explore the salience effect in food packaging across varied age groups and different cultures. Second, this study only involves three food categories, and all of them belong to "leisure food." Future studies can enrich and subdivide food categories (such as fresh food and cooked food) to investigate the generalization of the salience effect. Third, whether the crown in baseline packaging played as a novel stimulus in a way for some participants was not clear, which should be a more concern in future researches. Fourth, this study adopts traditional laboratory methods, which may be not enough to measure ecological validity. Besides, participants in the current study had known their task to assess willingness to purchase, which might drive their eye movement behavior. Future studies should use more ecological tasks as that in real-life shopping. Finally, in reality, transparent packaging not only allows the real food to be seen through a clear window but also allows consumers to get a full view of the food by shaking the package. However, the latter function is lost in the transparent packing images when viewed on a screen. This may be one of the reasons that diminished the advantages of transparent packaging in this study. Thus, researchers can use field experiments or VR technology to further improve the ecological validity of corresponding studies.

CONCLUSION

1. Both transparent and attractively graphic window packaging capture more attention compared to the baseline window packaging, but a transparent window does not always gain more benefit than an attractive image.
2. Transparent or graphic window packaging is recommended for the three studied foods, and graphic window packaging is specifically recommended for preserved fruits. Food manufacturers should pay attention to sensory studies to improve packaging design considering food categories.
3. Attractive packaging with salient elements helps to enhance consumers' willingness to purchase.

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 Academic Committee of Shaanxi Normal University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors contributed to the design of the study. XM conducted the data collection and analyses for the study. XM and GM programmed the experiments. XM, XZ, and GM wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Consumer Decision-Making Creativity and Its Relation to Exploitation–Exploration Activities: Eye-Tracking Approach

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Modern consumers face a dramatic rise in web-based technological advancements and have trouble making rational and proper decisions when they shop online. When they try to make decisions about products and services, they also feel pressured against time when sorting among all of the unnecessary items in the flood of information available on the web. In this sense, they need to use consumer decision-making creativity (CDMC) to make rational decisions. However, unexplored research questions on this subject remain. First, in what ways do task difficulty and time constraints affect visual attention on exploitative and exploratory activities differently? Second, how does the location of the reference (i.e., hints) influence the level of visual attention to exploitative and exploratory activities depending on affordance theory? Third, how do exploratory and exploitative activities affect CDMC? Eye-tracking experiments were conducted with 70 participants to obtain relevant metrics such as total fixation duration (TFD), fixation count (FC), and visit count (VC) to answer these research questions. Our findings suggest that task difficulty influences exploitative activity, whereas time constraint is related to the exploratory activity. The result of the location of hints aligns with the affordance theory for the exploitative activity. Besides, exploratory activity positively affected CDMC, but exploitative activity did not show any effect.

Keywords: creative consumer decision-making, eye-tracking, exploratory activity, exploitative activity, time constraints, task difficulty

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INTRODUCTION

Over the past decade, the concept of web-based product information has been overwhelmingly dominating the manufacturing industry as an essential tool for customer engagement. The overarching philosophy of web information is providing an interactive and enlightening resource to induce consumers to make a favorable purchase decision on products. However, this concept also brought problematic decision-making issues to both consumers and firms.

From the perspective of customers, because of the flood of information attributable to the digital revolution, it is imperative for customers to recognize correctly the benefits of the products they need among a variety of selections and then to make rational and creative decisions (Leeflang et al., 2014). However, the increase in consumer awareness and technological sophistication has

made it increasingly difficult for them to make rational purchasing decisions (Kulshreshtha et al., 2017). Typical consumers have busy lives and are time-constrained. Thus, they have difficulties in spending the considerable time required to make rational and appropriate choices. In this sense, they need to make creative decisions about the set of possible product attributes under extreme time pressure and conditions of selective overload (Reutskaja et al., 2011).

Meanwhile, as a vast range of similar products is introduced every day, competition in today's durable web markets has thus become quite intense. That being said, providing an informative, creative decision-making basis to consumers became a much more important activity that manufacturers utterly need to consider. However, because of the dynamic nature of consumer behavior (Seiler, 2013; Habibi et al., 2016), it would not be easy to come up with a strategic direction to induce the customers' creativity. In other words, discovering consumers' insights that could help enhance their creativity has recently forced manufacturers and brand managers to pursue productive and sustainable marketing strategies, launch new products, improve product quality, and implement new technologies (Kim and Han, 2014; Chung and Lai, 2017; Kim et al., 2020b).

Understanding how customers become creative in their decision-making using provided information would be necessary for conducting the design of website structures. Hence, field practitioners of manufacturing companies have worked together for a long while to identify and satisfy customers' creative decision-making to remain competitive in target markets. In this sense, it could be said that firms' business problem-solving to support consumers' creativity has been accumulating for a considerable amount of time and effort. When such creativity is used to its maximum to define and resolve customers' problems from their perspectives, firms' strategic goals in marketing may be accomplished with great success.

Previous studies have supported the positive effect of creativity on business success (Amabile, 1996; Perry-Smith, 2006; Althuizen and Reichel, 2016; Baack et al., 2016) from the perspective of corporations. Also, the individual-level creativity has been a motivating research topic in the field of psychology and business for a while (Shalley, 1991; Bharadwaj and Menon, 2000; Taggar, 2002; Pirola-Merlo and Mann, 2004; Hirst et al., 2009). Considering the importance as well as a substantial amount of time and effort investment of firms in consumers' creativity for decision-making, figuring out how to adequately induce consumers to utilize their creativity is crucial. However, the former research mostly emphasized the organization-level creativity that could facilitate insiders' creativity to enhance firms' business competitiveness (Amabile, 1996; Perry-Smith, 2006; Althuizen and Reichel, 2016; Baack et al., 2016), whereas few have investigated the importance of consumer creativity in decision-making (Rosa et al., 2014). Also, most of these studies employed self-report surveys that could be problematic (Farh and Dobbins, 1989). There could also be a strong likelihood of common methods bias when respondents report creativity using the self-report approach (Spector, 2006). Therefore, in this research, we conducted rigorous consumer-oriented creativity research that could advance theoretical perspectives, as well as provide practical implications that firms could apply to customer decision-making with creativity. By doing so, this study will be able to fill the gap by suggesting fruitful findings in the field of consumer creativity research that the previous research did not discover without facing a risk of bias, which might occur from using the self-report instrument.

This study adopted an eye-tracking approach in order to measure customer creativity in the processing of web information of smartphone products that measured such indices as total fixation duration (TFD), fixation count (FC), and visit count (VC), to investigate the way in which consumers' visual attention is associated with consumer decision-making creativity (CDMC) and the way in which exploitative and exploratory activities differ, depending on time constraints and task difficulty. By applying an eye-tracking approach, we could avoid possible bias that occurred from a self-report survey and derived more feasible outcomes. As a stimulus of the visual attention, we employed a java-based decision-making software, Web-HIPRE (Mustajoki and Hämäläinen, 2000), which derives to value-focused thinking (Turunen et al., 2018) (**Figure 1**). The outcomes of the participants on the web-HIPRE were also used in the CDMC assessments.

We addressed three specific research questions in this study: first, how do task difficulty and time constraints affect visual attention differently? Second, how does the location of the reference (i.e., hints) influence the level of visual attention to exploitative and exploratory activities, respectively? Third, does the notion of visual attention affect CDMC?

LITERATURE REVIEW AND HYPOTHESES

Exploitation vs. Exploration: Task Difficulty and a Time Constraint

The exploitation–exploration framework divides learning patterns broadly according to two aspects. In the definition of March (1991), exploration involves terms such as search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation, whereas exploitation includes such things as refinement, selection, production, efficiency, implementation, and execution. In particular, exploration would be riskier, with a higher possibility of failure, but it would bring more responsive and adaptive to turbulent market environments. Besides, exploitation is considered to be less risky and provide quicker returns, but it would be self-destructive in the long run. Citing Levinthal and March (1993), engaging in exploration entails the pursuit of new knowledge, of things that might come to be known, whereas engaging in exploitation involves the use and development of things known already.

At the individual level, exploitation is related to high-level engagement designed to optimize the performance of a current task; in contrast, exploration involves disengaging from the current task to experiment with new ideas that may result subsequently in radical innovations (Laureiro-Martínez et al., 2015). Exploitation may be more useful when reacting

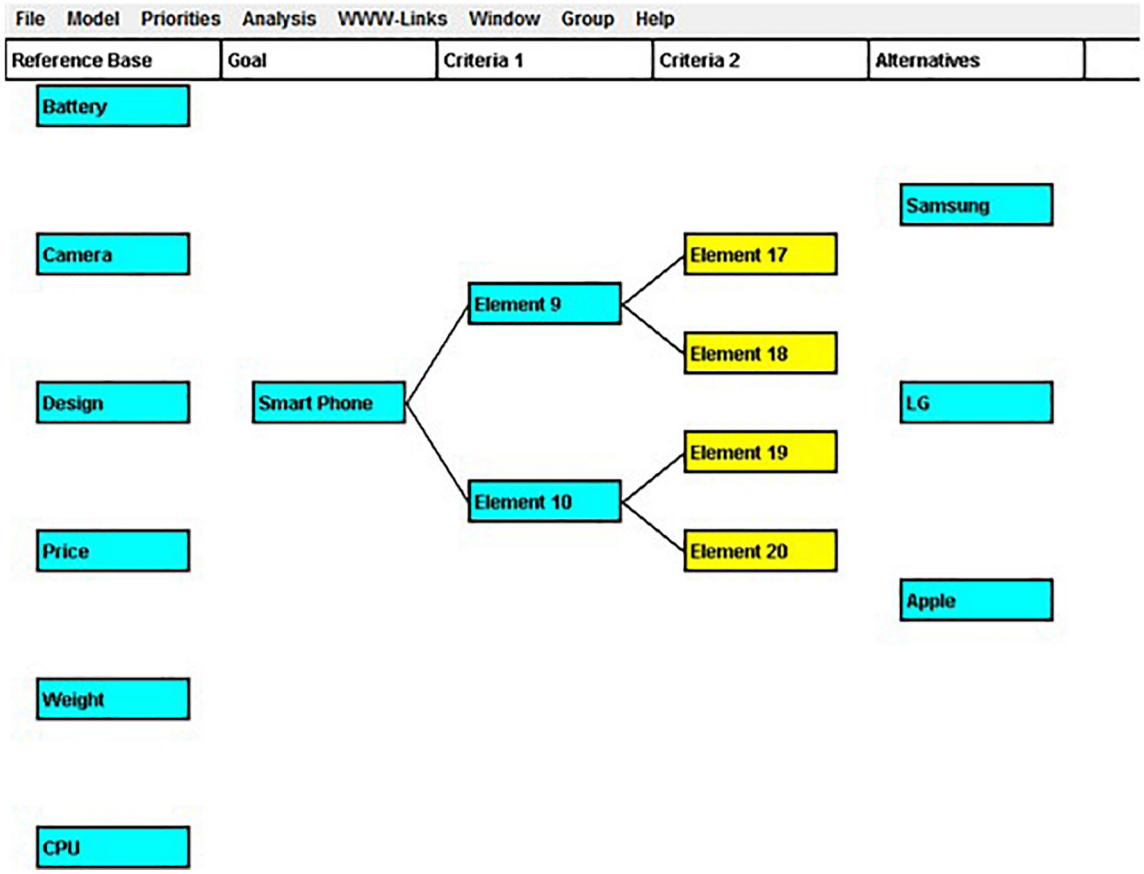

FIGURE 1 | Problem presentation window for decision-making.

to current environmental needs, compared with exploration because exploitation is associated with speedy and precise production. On the other hand, the outcomes of exploration have a longer time horizon and may even be less certain. Henceforth, exploration is recommended for long-term projects (March, 1991; Laureiro-Martínez et al., 2015).

From the perspective of CDMC, consumers' exploitation utilizes existing knowledge to make a quick and relatively more straightforward decision; for instance, when they are buying a well-known product or already possess enough information about the product. Conversely, exploration will be actively employed when consumers find it difficult to finalize making a purchase decision because intrinsic knowledge is insufficient, thus requiring additional knowledge from the exogenous source. However, when it comes to reality, both activities would be compulsory in the process of CDCM for specifically smartphone purchasing as a case in this research because most of the brand new smartphones are generally launched with novel functionality in terms of both hardware and software as well as features that consumers are already familiar with. Therefore, the combination of exploitation and exploration will continuously and naturally occur during the process of CDMC in innovative product purchasing, including smartphones.

Studies that address exploitation–exploration with eye-tracking methods are rare, although Beesley et al. (2015) conducted one such study. The authors' designated participants to play the role of a scientist who discovered a new chemical that could create a mutant organism, and the task was to design an experiment that predicted what mutations would occur when certain chemical pairs were mixed. They stated that uncertainty-based exploratory processes were more sensitive to contextual changes between training stages than were predictive-based exploitative processes. Another result of their experiment is that both exploitation and exploration had an influence on the attention participants paid to stimuli during associative learning; the exploitative attention process affected novel learning, whereas the exploratory attention process yielded results that are beneficial to learning.

There have been considerable studies on exploitation–exploration and creativity (Audia and Goncalo, 2007; Miron-Spektor et al., 2011; Seo et al., 2015) and also on creativity, task difficulty (Friedman and Förster, 2001; Chae et al., 2015), and time constraints. We based our research on the following antecedent studies: (1) assessment of a website's complexity and difficulty using eye tracking (Wang et al., 2014) and (2) consumer decision-making under time pressure measured

with similar metrics (Reutskaja et al., 2011). Greater task difficulty and time constraints would put consumers into more predicament. Therefore, we presume that participants would do more exploitative activities that might be safer and promise quicker returns with greater difficulty and given time constraint, whereas they would do more exploratory activities with lower difficulty and without time constraint. Thus, we performed eye-tracking experiments to test the following hypotheses related to exploitation–exploration and task difficulty, as well as exploitation–exploration and time constraints.

H1. Visual attention on exploitative activity will increase with a more difficult task, whereas visual attention on exploratory activity will increase with an easier task.

H2. Visual attention on exploitative activity will increase with a time constraint, whereas visual attention on exploratory activity will increase without time constraint.

Exploitation vs. Exploration: The Location of Information

The concept of affordability, which refers to attributes that can be executed between the world and actors (people or animals), was introduced in the book of Gibson (1979), *The Ecological Approach to Visual Perception*. It is defined as the nature of animal–environment interactions that determine behavioral outcomes. In other words, the question is explained by Affordance Theory based on the claim that familiar information or situations influence a person's behavior (Gibson, 1979; Michaels, 1988; Bub et al., 2018). The concept of affordance applied in our study took a different conceptual approach to that of Gibson and borrowed from Norman's Perceived Affordance Theory. In 1988, Norman began using the concept of affordance in his book, *The Psychology of Everyday Things* (POET), with respect to human–computer interaction (Norman, 1988). Norman introduced this term in the field of design to define specific attributes of physical artifacts that help us understand the way in which ergonomics should be manipulated. However, he later defined his theory as perceived affordance to differentiate it from real affordance because of the improper use of the term (Norman, 1999). Eichelman (1970) also discovered the effect of familiarity for simultaneous matching tasks. This notion signifies that familiar information and circumstances affect human behavior through experience or certain innate abilities, and people assess and respond to stimuli according to their perceptible attributes (Zhao et al., 2013; Boy et al., 2016).

These findings from the previous studies suggest that the concept of familiarity could be employed as a critical mass to decide the location of crucial information of products on web sites, such as a hint for discount, which might induce consumers to derive decision-making creativity. In that sense, exploitative activities would be significantly related to familiarity because exploitation is considered as improving and refining existing competencies and ideas. Employing what Atuahene-Gima (2005) stated, the exploitation of formulations with common ingredients extends current knowledge and seeks greater efficiency and improvements. When it comes to the location of web-based information, consumers conducting exploitative activities would be able to find it much adequate with familiar spots, for instance, the left side of the screen where all the filters and menus are generally located (Shrestha and Lenz, 2007).

Exploration, on the other hand, accompanies experimentation with new subjects and areas. Also, exploration entails the development of new knowledge through experimentation that fosters the variation and novelty needed for more radical changes (Laureiro-Martínez et al., 2015). In other words, exploration would require knowledge, habit, and behavior that are unfamiliar and more provocative compared to exploitation. In contrast to exploitation, consumers would go far beyond their familiarity when they do exploratory activities on the web-based information; thus, location familiarity of web information would not have any significant impact on their creative decision-making procedures.

According to Natraj et al. (2015), eye tracking has the advantage of being able to assess directly the effect of temporally assigning visual and spatial interests. Therefore, eye tracking would be a useful tool to reveal where vital information should be located on web pages. Based on these theoretical backgrounds, the following hypotheses were proposed to find out the relationship between the location of information, exploitation, and exploration.

H3a. When the hint position is located on the left side rather than the right side, visual attention in exploitation activity will be more concentrated.

H3b. Hint location will not affect the concentration of visual attention in exploration activity.

Creativity and Visual Attention

According to previous research on the subject since Guilford's groundbreaking presidential address to the American Psychological Association in 1950 (Guilford, 1950), numerous definitions of creativity in business have been proposed. Then, these definitions gradually have become more sophisticated (Perry-Smith, 2006; Yeh et al., 2016). Many past researchers have paid significant attention to the positive effects of creativity (Goldenberg et al., 1999; Smith and Yang, 2004; Baack et al., 2016) and analyzed ways in which to enhance it (Suh et al., 2010; Bai et al., 2016; Yang and Yang, 2016). It is because the positive effect of creativity is an underlying source of innovation that can catalyze an organization's growth (Woodman et al., 1993). Also, studies of creativity have advanced in various areas, including business, social science, and engineering, among others. Consumers' creativity in this study employed the arguments of Guilford (1965) and Hirschman (1980) that productive thinking to generate the solution during the process of decision-making in purchasing a product on the website using relevant and adequate information provided. Hirschman (1980) also suggested that creativity is essential during the problem-solving process; thus, consumers' creativeness would be the fundamental component for making a decision in the purchasing progression. However, relatively less attention has focused on studying CDMC.

The eye-tracking technique has been adopted to examine human visual attention based on the eye–mind assumption (Just and Carpenter, 1980). In general, the location on which the eye fixates reflects attention, whereas fixation duration reflects processing difficulty and amount of attention (the longer the information is fixated, the more complex it is or the more deeply it is processed). Specifically, fixation duration varies depending on the type of information (e.g., text vs. graphics) and type of task (e.g., reading vs. problem-solving). Further, fixation locations and duration reflect the individuals' reading strategies and prior knowledge or experience (Hyona et al., 2002). Besides, scan path patterns indicate the cognitive strategies individuals use in goal-oriented tasks (Gandini et al., 2008). Thus, eye tracking has been found to be a useful method in psychology to study cognitive processes, largely because of the assumed link between attention and what we look at Rothkopf et al. (2007). Eye movements are associated closely with shifts in attention—in that our eyes may be drawn unconsciously to something of interest, and our attention follows, or we may choose to look at something to direct our attention to it. A variety of research supports this idea that changes in fixation reflect changes in the focus of our attention (Lee and Ahn, 2012).

Eye movement often is used in creativity research because the eye tracker can track eye dynamics precisely and navigate the internal cognitive processes that cannot be seen in overt behavior (Huang, 2017). According to Yeh et al. (2014), the amount of attention, eye movement, and working memory interact to affect problem resolution. Drawing on these previous studies, we proposed the following hypotheses on the relations between exploitation–exploration, creativity, and the notion of visual attention.

> H4. The greater the visual attention on exploratory work, the higher the CDMC will be.

Web-HIPRE

Web-HIPRE (HIerarchical PREference analysis on the World Wide Web) (Mustajoki and Hämäläinen, 2000) is a java-based software for multicriteria decision analysis tool. It is based on HIPRE 3+ (Hämäläinen and Lauri, 1995), a well-known software of decision-making support system (Turunen et al., 2018). It has been frequently used as an essential tool for multicriteria decision analysis that is harnessed for creative problem-solving (Geldermann et al., 2009; Vacik et al., 2014). It also provides an implementation of multiattribute value theory (Keeney and Raiffa, 1993) and the analytic hierarchy process (AHP) (Saaty, 1990, 1994; Salo and Hämäläinen, 1997) to support the different phases of decision analysis such as structuring of the problem (French et al., 1998), prioritization, and analyzing the results (Mustajoki and Hämäläinen, 2000).

MATERIALS AND METHODS

This study was conducted with the approval of Sungkyunkwan University, in compliance with the guidelines and regulations of the university institutional review board (IRB no. 2017-12-011-022) for the method.

Participants

A total of 80 physically and mentally healthy undergraduate students from Sungkyunkwan University in Seoul were recruited to participate in two experiments, which have different conditions in task difficulty and time constraint. The participants were selected randomly to avoid the error that may occur because of an unequal distribution of grades and majors. Among them, a total of 70 data points (33 for task difficulty and 37 for time constraint studies) were analyzed, excluding 10 participants: four extreme outliers and six unsuccessful eye-tracking calibrations. Thirty-eight of the 70 participants were females: 20 in the task difficulty group and 18 in the time constraints group. Participants' mean age was 23.16 [standard deviation (SD) = 1.78]. The Web-HIPRE screen with area of interest (AOI)–Reference on the left side was assigned to 15 participants for the task-difficulty experiment and 17 people for the time-constraint experiment. The easy task was assigned to 17 of 33, and the time-constraint option was applied to 18 of 37 (**Table 1**). We ensured that no one had participated previously in a similar eye-tracking experiment and instructed participants to avoid excessive drinking or lack of sleep before taking part in the experiment. In order to obtain more precise eye-tracking data, the participants were asked not to wear contact lenses and excluded those who had severe astigmatism.

Procedure

Upon arrival, participants were asked to fill out a questionnaire that included demographic information. In addition to the questionnaire, a detailed explanation about the experimental procedure and the tracking device was provided, including a device-mounted eye tracker that would record their eye movements unobtrusively. After participants agreed, the calibration process was carried out. Before performing the task, they watched a training video that guides how to use Web-HIPRE. The formal experiment began after confirming that the participants had a good understanding of the procedure.

Before starting the eye-tracking experiment, the participants' eye points were calibrated using Tobii studio software (version 3.3, Tobii Technology) to ensure that measurements would be made accurately and precisely on the experiment's AOIs. They were requested to sit at a distance of 65 cm from the screen with minimal movement as possible. Thereafter, the visual attention data were recorded while the participants developed a decision-making model by harnessing the Web-HIPRE program. Thereafter, the eye tracker measured their eye movements while the participants developed a decision-making model using the Web-HIPRE program. Participants were given the following decision-making tasks: "Let's assume you are buying a smartphone. Which product would you buy from Samsung, LG, and Apple?" Then the participants were presented with the screen shown in **Figure 1**. To address this decision-making problem, participants worked on Web-HIPRE to configure criteria to be applied, supposing they purchase a smartphone model based on their preferred attributes. The reference base menu for participants included six categories: batteries, cameras, designs,

TABLE 1 | The distribution of the participants for task difficulty, time constraint, and hint location.

	Task difficulty		Time constraint		Sum
Manipulation	**Easy**	**Difficult**	**Yes**	**No**	
	17	16	18	19	70
Hint location	**Left**	**Right**	**Left**	**Right**	
	15	18	17	20	70

prices, weight, and CPU, which are used widely in smartphone comparisons. Participants would implement a primary decision-making strategy by deciding whether to exploit the reference base menu in the decision-making process. The Web-HIPRE automatically presents the final decision result based on the criteria suggested by the experiment participants (**Figure 2**). The Web-HIPRE screen consists of three AOIs: reference, task activity, and alternatives as marked with AOI-reference, AOI-activity, and AOI-alternatives in **Figure 3**, respectively.

Manipulations

Stimulus: Web-HIPRE

For this experiment, we harnessed the Web-HIPRE[1], which is a decision support system (DSS) developed by the Systems Analysis Laboratory of Aalto University's School of Science and Technology. It is used as an AHP for decision support (Mustajoki and Hämäläinen, 2000) and is the first web-based DSS software with multicriteria (Mustajoki et al., 2004). The software helps users make informed decisions by developing decision-making models and processing the prioritization of each option. The experimental paradigm included watching a video on how to use the DSS software, Web-HIPRE with the following instruction:

> "You can set 4 top comparison criteria (2 for easy task participants) in Criteria 1, and create two subelements for each element belonging to Criteria 1. (Therefore, the number of elements in Criteria 2 is all eight. For easy task participants, the elements in Criteria 2 are all four.) At this time, double-click to create element boxes. To change the name, click once, and press Enter key. After creating elements, you need to connect the parent and child items. To connect, click the parent item to the left and right-click the child item. Once all the criteria have been linked, you can evaluate each alternative according to the eight (or four) comparative items in Criteria 2. When writing, you can use the items in the reference base or produce the new standard. After completing the connection, you need to set the priority. To determine the priority, go to the 'AHP' submenu of the 'Priorities' menu. Pairwise comparisons options are given, and you can weigh them according to how vital their attributes are to your decision. When all settings are completed, you can check the result by visiting the 'Composite Priorities' submenu in the 'Analysis' menu" (**Figure 2**).

[1]http://hipre.aalto.fi/

Task Difficulty

In this study, we compared the level of CDMC and the results of eye tracking between two groups, one of which performed a simple task, whereas the other engaged in a more difficult one. Task difficulty was assessed by applying the innovative idea of Wang et al. (2014), which the manipulations were related directly to the complexity of the selection options in the task areas of the Web-HIPRE screen (the number of elements for making a decision what smartphone model they will purchase). The easy task was to create six elements, two for Criteria 1 and four for Criteria 2, while a difficult task was instructed to consist of 12 elements: four for Criteria 1 and eight for Criteria 2. Seventeen of 33 participants conducted the easy task.

Time Pressure

Time constraints for performing the decision-making task through Web-HIPRE were assigned to 18 of 37 participants, and the remaining 19 subjects were not provided with this notification. The 18 participants were informed that the reward scheme differs, depending on the time spent in completing the task. The alert was given to them that they would be paid 5,000 WON (about US $5) for completing the decision model within 1 min, 4,000 WON for 2 min after that, and 3,000 WON for longer than 2 min. However, during the postexperiment debriefing session, they were told that the notice of differential payment was a deception necessary for the experiments, and they all would receive the 5,000 WON. Those who participated in the time-constraint experiment were instructed to implement the hard task option.

Measures

Visual Attention

Eye movements were detected and recorded with the Tobii X2-60 eye-tracking system, which has a 60-Hz sampling rate (SD, approximately 1 Hz: Tobii Technology, 2014). In this experiment, the visual attention patterns were presented on a screen (CRT 25 inches, 1,920 × 1,080 resolution) connected to a desktop computer that is compatible with the Tobii Studio software (v. 3.3). The accuracy and special resolution of the instrument are specified as 0.40° and 0.340°, and the total system's latency to access data for the eye positions is less than 32 ms. The Tobii X2-60 system permits both dark and bright pupil tracking as underpinning automatic optimization. In this study, when participants performed tasks in the Web-HYPRE DSS, visual attention was measured in three AOIs using an eye-tracking tool. TFD, FC, and VC were employed as the metrics of visual

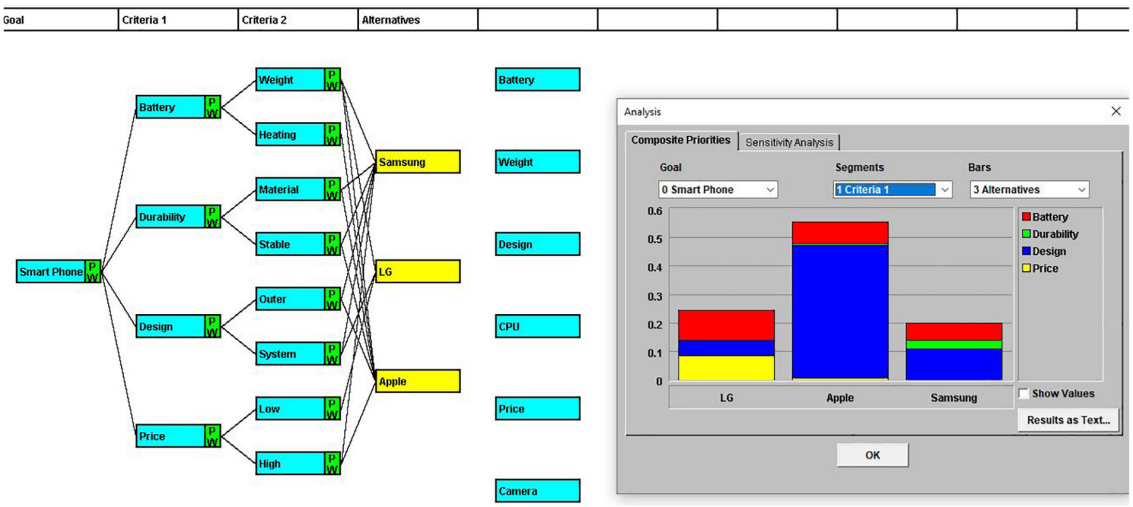

FIGURE 2 | An outcome of decision-making through Web-HIPRE task.

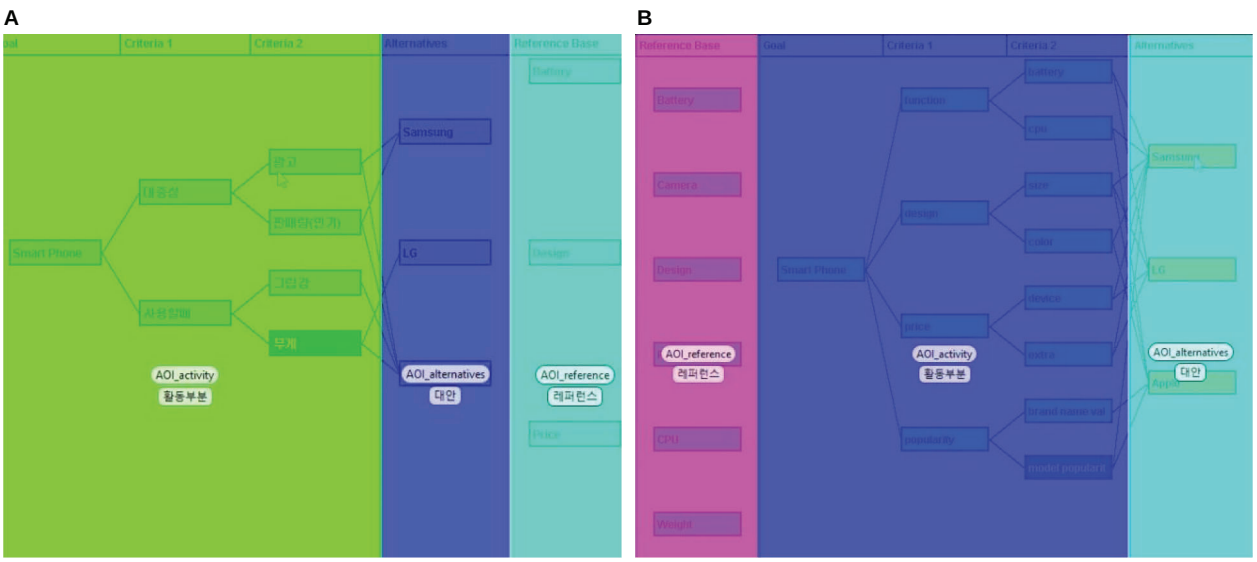

FIGURE 3 | Windows that show easy **(A)** and hard **(B)** tasks with three AOIs. **(A)** Easy task locating reference base on the right side. Note 1: AOI-Activity is visible at the left, and AOI-Alternatives is illustrated in the middle. Three hint nodes are given in the AOI-Reference on the right: battery, design, and price. Note 2: The participant created two nodes in Criteria 1, popularity, and ease of use. The subattributes were organized as follows: popularity advertisement and sales volume, and ease of use grip, and weight. **(B)** Hard task locating the AOI-Reference on the left side. Note 1: AOI-Activity is visible from the middle, and AOI-Alternatives is illustrated at the right. Six hint nodes are given in the AOI-Reference on the left: battery, camera, design, price, CPU, and weight. Note 2: The participant created four nodes in Criteria 1, function, design, price, and popularity. The subattributes were organized as follows: function-battery and CPU, design-size and color, price-device and extra, and popularity-brand name value and model popularity.

attention. TFD represents the total fixed time within a specific AOI, whereas FC corresponds to the number of times that eyes are fixed on a specific AOI. VC is measured by the number of times the participant's gaze enters the AOI (Ares et al., 2013; Pfeiffer et al., 2020). The Web-HYPRE DSS screen was divided into three AOIs: reference, task activity (from now on referred to as activity), and alternatives. The eye-tracking measures in the AOIs were not normalized for the values in any specific area. Activity is an area where participants are supposed to create elements of Criteria 1 based on their needs and come up with two elements per element of Criteria 1 in Criteria 2, for the sake of deriving the most desirable of the three alternatives. Each element of Criteria 1 must be linked to two elements in Criteria 2. The connection between elements in Criteria 2 and the alternatives is determined considering the relationship between the elements and three smartphones in the alternative area. The reference area (displayed on the screen as a reference base) is designed to be randomly located on the right or left side. Participants

were instructed to refer to the hints given in the reference base (three for the easy task and six for the hard task) or rely on their ideas without consultation to the hints. Visual attention in the reference area was defined as an exploitative activity in our research model, drawing on the exploration–exploitation theory. Exploration was the value obtained by subtracting the visual attention value from the reference area from the corresponding value in the activity area since exploratory work is involved in original ideas, not an approach to improving existing knowledge or information. Participants were allowed to generate elements of the activity area (AOI-activity) in Korean or English. The Tobii program was launched with the Web-HIPRE screen open. Before starting the eye-tracking experiment, the participants' eyes were calibrated to help fixate the three AOIs in the Web-HIPRE display. They were asked to observe the display areas by moving their pupils while keeping their body steady posture following the red dot that moves during calibration. The recording of the eye tracking continued until the decision model was completed.

Exploitative and Exploratory Activity

We employed the visual attention tools measured by the eye tracker and conducted a *t* test to verify that there were significant mean differences between each pair (e.g., easy vs. hard and with time constraints vs. without the option). The level of exploitative activity was defined by the values of the visual attention indices for the AOI-reference that the participants could use as a hint to perform the task; the level of exploratory activity was calculated by subtracting the visual attention value for the AOI-reference nodes from that for the AOI-activity; thus, exploration represented the extent to which subjects solved the task without help from the hint provided. Exploration was graded according to the number of criteria that participants created based on their original ideas without using the references presented (March, 1991; Laureiro-Martínez et al., 2015). On the other hand, exploitation was obtained from the visual attention values for the reference site, as they signified the extent to which the participants used general ideas, made efficient selections from the information provided, and tried to optimize their performance of a particular task (Laureiro-Martínez et al., 2015).

Consumer Decision-Making Creativity

In our experimental model, the CDMC criterion was based on the method that Hsiao et al. (2017) used to evaluate creativity. The detailed evaluation criteria for each activity are as follows:

> Novelty: Ability to derive decision-making processes and results from his/her own ideas that are not presented by the reference nodes.
>
> Rationality: The ability to make logical links in the decision-making process: It is evaluated by judging whether the links between elements of Criteria 1 and 2 and alternatives logically match.
>
> Usefulness: The degree to which the practical use of the smartphone is considered. It is measured considering whether the contents given in the Criteria 1 and 2 are suitable for the overall evaluation items of the actual smartphone users.

Using the consensus assessment technique (Amabile, 1982; Althuizen and Reichel, 2016), two creativity assessment experts were invited to evaluate the outcomes of the participants' works on Web-HIPRE. Each of the two raters assessed the three areas of creativity (e.g., novelty, rationality, and usefulness), without prior knowledge of each participant's major, gender, and age. The raters used the five-point scale, which was anchored at 1 = "not at all" and 5 = "very agree" (Rosa et al., 2014). The total score of CDMC evaluation is in the range of 3–13 points. The interclass correlation coefficient (ICC) (Shrout and Fleiss, 1979; Baer and Oldham, 2006) of the total score showing measures of agreement among the multiple raters was 0.877 (F = 8.131, p = 0.000). CDMC was computed by averaging the scores of both raters for the three evaluation criteria. The ICCs for novelty, rationality, and usefulness were calculated as 0.775 (F = 4.446, p = 0.000), 0.782 (F = 4.582, p = 0.000), and 0.836 (F = 6.083, p = 0.000), respectively. Therefore, it is judged that there is a satisfactory agreement between the two experts.

RESULTS

We conducted a multiple regression analysis with the predictors of task difficulty, hint location, and time constraint on exploitative (ET) and exploratory (ER) visual attentions employing three metrics such as TFD, FC, and VC. The regression models of the ET gauged by the three visual attention metrics were adopted with a relevant fitness: adjusted R^2 = 0.182, F = 6.122, $p < 0.001$, for TFD; adjusted R^2 = 0.326, F = 12.145, $p < 0.001$, for FC; adjusted R^2 = 0.237, F = 8.139, $p < 0.001$, for VC (**Table 2**). On the other hand, for ER, only the FC regression model showed significance: adjusted R^2 = 0.008, F = 1.196, $p > 0.05$ for TFD; adjusted R^2 = 0.107, F = 3.761, $p < 0.05$, for FC; adjusted R^2 = 0.048, F = 2.170, $p > 0.05$, for VC (**Table 3**). Task difficulty predictor showed a positive effect on ET in terms of TFD, FC, and VC visual attention metrics. That is, it suggests that if the task is difficult, people refer to and improve existing information or knowledge (exploitative activity) (TFD: β = 0.364, p = 0.002; FC: β = 0.415, p = 0.000; and VC: β = 0.379, p = 0.001) (**Table 2**). However, the predictive effect of task difficulty on ER activity was not verified (**Table 3**). Therefore, H1 was partially supported, which demonstrated that the participants engaged more ET activity when the task was harder, but the task difficulty had no effect on the ER behavior. We also hypothesized that ER activity gauged by visual attention metrics increases in the absence of time constraint and that ET activity increases because of time constraint manipulation (H2). The effect of the time-constraint variable was verified only for ER activity measured by FC metric, but not in the other five regressions. In the absence of time constraint, the ER activity in FC metric significantly increased (β = 0.354, p = 0.005; **Table 3**). Thus, H2 was partially supported. Further, we hypothesized that the visual attention to ET activity is more concentrated when the hint location is on the left rather than on the right (H3a), but the test result was calculated opposite to the assumption of H3a. Namely, when hint nodes were located on the right side, participants engaged in more exploitative activities; β = 0.311, p = 0.006 for

TABLE 2 | Effects of task difficulty, hint location, and time constraint on exploitative visual attention in terms of TFD, FC, and VC metrics.

Visual attention metric	Variable	Standardized coefficient	*P*-value	Adjusted R^2	*F*
		β			
TFC	Task difficulty	0.364	0.002**	0.182	6.122**
	Time constraint	0.099	0.393		
	Hint location	0.311	0.006**		
FC	Task difficulty	0.415	0.000***	0.326	12.145***
	Time constraint	0.021	0.84		
	Hint location	0.428	0.000***		
VC	Task difficulty	0.379	0.001**	0.237	8.139***
	Time constraint	−0.047	0.677		
	Hint location	0.329	0.003**		

*N = 70. **p < 0.01, ***p < 0.001. Significance levels are two-tailed. Note. If the hint location variable's β is computed to positive, it means that the right position has a positive effect on the dependent variable. Positive β of task difficulty means that the hard task affects the dependent variable positively. Positive β of the time constraint variable means that the time constraint manipulation adversely affects the dependent variable.*

TABLE 3 | Effects of task difficulty, hint location, and time constraint on exploratory visual attention in terms of TFD, FC, and VC metrics.

Visual attention metric	Variable	Standardized coefficient	*P*	Adjusted R^2	*F*
		β			
TFC	Task difficulty	0.183	0.155	0.008	1.196
	Time constraint	0.184	0.152		
	Hint location	−0.081	0.500		
FC	Task difficulty	0.203	0.098	0.107	3.761*
	Time constraint	0.354	0.005**		
	Hint location	−0.164	0.155		
VC	Task difficulty	0.196	0.121	0.048	2.170
	Time constraint	0.110	0.381		
	Hint location	−0.233	0.051		

*N = 70. *p < 0.05, **p < 0.01. Significance levels are two-tailed. Note. If the hint location variable's β is computed to positive, it means that the right position has a positive effect on the dependent variable. Positive β of task difficulty means that the hard task affects the dependent variable positively. Positive β of the time constraint variable means that the time constraint manipulation adversely affects the dependent variable.*

TFD; β = 0.428, $p = 0.000$ for FC; and β = 0.329, $p = 0.003$ for VC (**Table 2** and **Figure 4**). On the other hand, we hypothesized that the placement of hint nodes would not affect ER activity. As the location of the hint node has no statistical significance for the effect on ER activity (**Table 3**), H3b may be adopted.

We performed multiple regression employing the CATREG (optimal scaling categorical regression) routine to test the effects of exploitative and exploratory visual activities on CDMC as measured by eye-tracking tool and experts' assessments, which depicted the results in **Table 4**. The CATREG routine was developed by the Data Theory Scaling System Group (DTSS) at Leiden University and is a descriptive, non-linear multivariate procedure that is available in SPSS (van der Kooij et al., 2006; Kooij, 2007; Ruiz et al., 2011). CATREG performs an "optimal scaling" regression analysis that allows simultaneous scaling of nominal and continuous variables and optimization of model fitness with various scaling levels. An optimal model fit was achieved by designating all of the independent variables as "numeric" and the dependent variable (CDMC) as "ordinal" (adjusted $R^2 = 0.244$, $F = 2.933$, $p < 0.05$). The dependent variable was discretized to six groups employing the normal distribution option. In terms of the FC metric, exploratory activity influenced CDMC positively (β = 0.917, $p = 0.002$). Based on the test result shown in **Table 4**, H4 was partially supported.

GENERAL DISCUSSION

Key Findings and Implications of the Study

Our experiments provided the following key findings by using the eye-tracking device to measure visual attention with Web-HIPRE. Our findings contribute to the academic discipline by presenting new perspectives of visual attention, exploitation–exploration activities, and CDMC in a Web-HIPRE game environment. In particular, research on creativity in consumers' decision-making is scarce, although its importance is not easily ignored.

First, from the experimental results of consumers' decision-making employing the Web-HIPRE game, task difficulty affected participants' visual attention to the exploitative activity. In contrast, time constraints had an adverse effect on exploratory

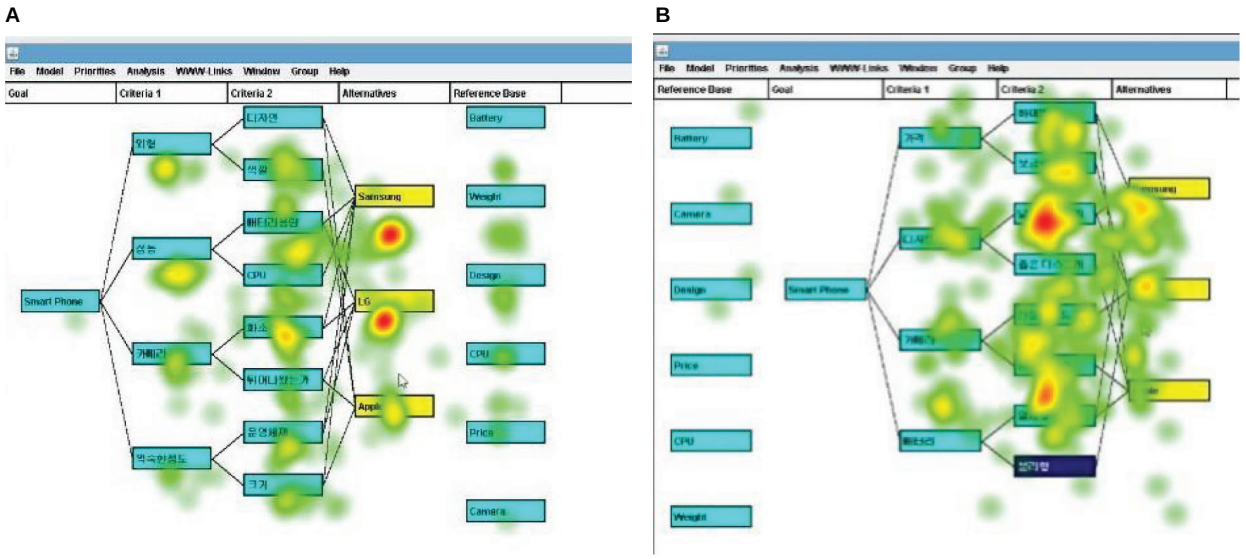

FIGURE 4 | Heat maps of Web-HIPRE game activities for the hard task. **(A)** Heat map when locating the AOI-Reference on the right. **(B)** Heat map when locating the AOI-Reference on the left.

TABLE 4 | Effects of exploitative and exploratory activities on CDMC.

ET and ER activities	Variables (visual attention metric)	Standardized coefficient	*P*	Adjusted R^2	*F*
		β			
ET	TFD	−0.178	0.940	0.627	3.158*
	FC	−0.761	0.356		
	VC	1.055	0.178		
ER	TFD	−0.700	0.286		
	FC	1.162	0.002**		
	VC	−0.658	0.140		

*N = 37. *p < 0.05. **p < 0.01. Note 1. ET and ER stand for explorative and exploratory activities, respectively. Note 2. The variables are based on visual attention metrics per minute. Note 3. This regression model was analyzed with a group for the time-constraint experiment.*

activity. (1) The more difficult the task, the more likely participants were to fixate on the AOI-reference more frequently and for a longer period and (2) compared with the time constraint option manipulated by incentive, the participants' visual attention to exploratory activity was greater in the absence of time constraints. However, the time constraint factor did not influence the exploitative activity. The results are consistent with an antecedent study by Lee and Meyer-Doyle (2017) that individuals' exploration activities get weakened when incentivizing for their performances; namely, the exploratory activity is negatively affected by the time constraint option where the reward amount increases as the task execution time lessens.

By comparison with people who undertake easy tasks (involving less complex decisions), those with difficult tasks (more complex decisions) grapple with the problems and endeavor to come up with a creative idea that leads ultimately to a better outcome. Drawing on the study of Bang and Wojdynski (2016), people have a propensity to attend more and longer when they engage in tasks with high cognitive demand, while they attend relatively less to a simple task that requires little cognitive effort. At the individual level, exploitation is defined as behavior that is related to the selection and improvement of existing ideas designed to optimize the performance of a current task. In contrast, exploration involves departing from current capabilities and general ideas to perform new experiments and derive new ideas and outcomes (March, 1991; Laureiro-Martínez et al., 2015). Drawing on the results of the experiment that employed a Web-HIPRE game to assess creative decision-making in a mobile phone purchase, the participants tended to actively use the hints presented on the screen when engaged in a more complex problem. As the number of attributes required for decision-making increases, the decision-making process becomes more difficult. Based on our analysis of the experimental results, it is inferred that people tend to seek information by searching the surroundings more extensively in these situations.

Another finding was that exploitation was involved more when the hint nodes were placed on the right rather than on the left side of the screen, such that, when locating the reference (hint nodes) on the right side, they directed greater visual attention to the area of reference, opposite to our expectation that the left

side would be more familiar to the subjects and more involved in exploitation because many websites have filters and menus on the left side. In alignment with Norman's perceived affordance theory (Norman, 1999), influenced by Gibson's affordance effect, which signifies that familiar information and circumstances affect human behavior (Gibson, 1979; Michaels, 1988; Bub et al., 2018), we could interpret this result that the subjects' habit of reading information from the left side to the right side was affected. It is speculated that visual attention was higher when placing hint nodes on the right than on the left side because it would be more familiar and convenient to look at the right side than the left side of the primary information to discover a hint during the work because of the natural flow of the language interpretation that generally starts from the left to the right since they were infants (Chokron and De Agostini, 1995; de Hevia et al., 2014; Göbel, 2015). From this point of view, depending on the target group's characteristics (i.e., habits in languages), the designs of offline advertisements or web pages can be considered by applying the affordance theory.

Table 4 depicts that CDMC is not expected to increase even if the exploitation activity enhances, whereas the visual exploratory activity positively affects CDMC. The increase in exploratory activity is found in those who have driven creative decision-making, aligning with previous research claims that individuals with the exploratory propensity produce better decision-making outcomes (Laureiro-Martínez et al., 2015; Lee and Meyer-Doyle, 2017). This result also suggests that the external information does not have a decisive influence on the creative purchasing decision (manufacturer's explanation or advertisement), given the exploitative activity was not determined as a significant predictor.

Implications for Marketing Practice

Our results have some interesting implications for both practice and management. First, recent trends in online shopping homepages show that sufficient information is displayed on the screen to attract consumers' attention. This issue often confuses and imposes a cognitive overload because consumers are required to make complex decisions. In this respect, our results revealed that relevant phrases and information need to be arranged on the right side of the online shopping screen to help consumers make purchase decisions in cases in which target products require complex decision-making.

Second, it would be quite useful for companies to use creative consumers to find the existence of unsatisfactory needs remaining in the target market when preparing new products. Because creative consumers were unexpectedly able to disclose the existence of unmet needs in the target market, this insight could be useful to acquire a competitive advantage for firms in the fierce competition among companies. Therefore, companies must be prepared well to identify creative consumers.

Limitations and Future Research Suggestions

Despite our findings, there still are limitations to this research. First, this study only employed monocultural data samples acquired from Korean student. As the application of country classification is essential for global firms such as smartphone manufacturers to set up an international marketing strategy, as Helsen et al. (1993) and Lysonski et al. (1996) proposed, a further utilization with several data samples gathered from consumers in different countries would be much helpful for field practitioners to discover hidden ethnic heterogeneity. Also, because of the single type of participant for the experiments (Korean and student), this study's results could be limited. The results might differ if considering subjects with different age groups and other life habits in terms of work, family, language, or culture. Hence, a future study can examine cultural differences, including consumers from several backgrounds (e.g., Korean vs. US consumers and students vs. permanent employees) on similar research topics.

Next, this study focused only on the creativity of consumers. However, there are still evocatively relevant links between consumers' creativity, innovativeness, and novelty-seeking (Hirschman, 1980), and innovative consumers tend to acquire a significantly provocative value (Kim et al., 2020a). In particular, if we consider smartphones are a collection of innovations, a future study would be necessary to take other innovativeness and novelty traits of consumers with creativity into account in order to derive more fruitful outcomes.

Also, besides various advantages of the eye-tracking experiment, there are still a few disadvantages: approximately 10% to 20% of participants cannot be examined because of contact lenses, glasses, and pupil colors (Jacob and Karn, 2003); outcomes from eye-tracking experiments could not be the only impactful measurement to discover the intention of consumers and thus might need additional evaluations (Orquin and Loose, 2013). Therefore, we suggest researchers in the field use integrated approaches such as eye tracking with functional near-infrared spectroscopy (fNIRS) or eye tracking with electroencephalography (EEG), and then it would be possible to draw many beneficial findings without facing bias from self-report surveys.

Lastly, this research used the conceptual e-commerce environment using a Web-HIPRE game to evaluate consumers' creative decision-making in a mobile phone purchase. Hence, we suggest that this study's results also need to be confirmed in a standard e-commerce environment in future research.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because datasets used for this study require participants' consent before being shared with others. Requests to access the datasets should be directed to KL, kunchanglee@gmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the IRB of Sungkyunkwan University. The

patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EC designed the experiment, collected and analyzed the data, drafted and revised the manuscript. CK assisted with the experiment, analyzed the data, and drafted and revised the manuscript. KL supervised the experimental design and the data collection and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Contribution of Eye-Tracking to Study Cognitive Impairments Among Clinical Populations

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In the field of psychology, the merge of decision-theory and neuroscientific methods produces an array of scientifically recognized paradigms. For example, by exploring consumer's eye-movement behavior, researchers aim to deepen the understanding of how patterns of retinal activation are being meaningfully transformed into visual experiences and connected with specific reactions (e.g., purchase). Notably, eye-movements provide knowledge of one's homeostatic balance and gatekeep information that shape decisions. Hence, vision science investigates the quality of observed environments determined under various experimental conditions. Moreover, it answers questions on how human process visual stimuli and use gained information for a successful strategy to achieve certain goals. While capturing cognitive states with the support of the eye-trackers progresses at a relatively fast pace in decision-making research, measuring the visual performance of real-life tasks, which require complex cognitive skills, is tentatively translated into clinical experiments. Nevertheless, the potential of the human eye as a highly valuable source of biomarkers has been underlined. In this article, we aim to draw readers attention to decision-making experimental paradigms supported with eye-tracking technology among clinical populations. Such interdisciplinary approach may become an important component that will (i) help in objectively illustrating patient's models of beliefs and values, (ii) support clinical interventions, and (iii) contribute to health services. It is possible that shortly, eye-movement data from decision-making experiments will grant the scientific community a greater understanding of mechanisms underlining mental states and consumption practices that medical professionals consider as obsessions, disorders or addiction.

Keywords: clinical research, cognitive impairments, consumer science, eye-tracking, neuromarketing, translational practice

To consider the state of the decision-maker
translated by the beholder's eyes is our goal

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INTRODUCTION

Consumers make decisions at their own pace. Their choices are significantly influenced by personal preferences, situational context of the decision, such as presence of time pressure and size of the opportunity set (a number of given alternatives) as well as the environment of the point of purchase (Baldwin et al., 2012; Venkatraman et al., 2012; Berčík et al., 2016; Spence et al., 2016; Cherubino et al., 2019; Lin et al., 2019; Wolf et al., 2019; Vriens et al., 2020). Importantly, consumers are usually not aware of the steps of simplifying the decision processes by eliminating (ignoring) some information and paying attention (giving more time) to certain, considered options. Hence, technological advances that enable to isolate key processes, which underlay individuals' preferences and reactions (e.g., buying behavior), attain increasing attention of the media, user analysts and researchers (Hubert and Kenning, 2008; Chynal et al., 2016; Oliveira et al., 2016; Gidlöf et al., 2017; Touchette and Lee, 2017; Spence, 2019).

The application of neurophysiological tools recording brain measures (e.g., electrical brain activity, functional near-infrared spectroscopy, BOLD-contrast imaging used in functional magnetic resonance imaging, fMRI) and non-brain measures (e.g., electrodermal response, heart rate, eye-tracking), as adjuvant instruments to behavioral data in marketing research, is not a new concept (Levy et al., 2011; Berčík et al., 2016; Cherubino et al., 2019). Studies of eye-movements through direct observations were conducted already in the 1800s. An early form of an eye-tracker was built by Edmund Huey in 1908 and first non-intrusive eye-tracker was constructed by a pioneer in experimental educational psychology — Guy Thomas Buswell, known for groundbreaking investigations on recording and analyzing subjects' eye movements (Buswell, 1935). Buswell's results indicated that observers often fixated on the same spatial locations in an image, but not necessarily in the same temporal order. Moreover, the viewers' eyes tended to focus on foreground elements (e.g., faces and people) rather than background elements (e.g., clouds or foliage). In 1945, Brandt, 1945 published a general analysis of eye movement patterns of participants, who looked at advertisements. Similarly to Buswell, Brandt concluded that there are noticeable, individual differences in eye movements, but in general, these behaviors are similar enough in order to formulate "psychological laws" (see Babcock et al., n.d.)

The work on the relationship between eye-movements and the sequence of thought processes has been greatly extended by a Russian psychologist Alfred Lukyanovich Yarbus, who believed that the viewers' eyes were directed toward areas of the stimulus that were "useful or essential" to perception. Recorded eye-movements of examining Ilya Repin's painting *"An Unexpected Visitor,"* provided key findings on the substantial influence of experimental task on viewer's eye-movements (kindly refer to the book Yarbus, 1967, which is often quoted among researchers investigating the relationship between fixations and interest, Mackworth and Bruner, 1970; Noton and Stark, 1971; Walker Smith et al., 1977; Hayhoe and Ballard, 2005; Unema et al., 2005; Castelhano et al., 2009; Greene et al., 2012; Borji and Itti, 2014; Martinez-Conde and Macknik, 2015; Boisvert and Bruce, 2016; Smith et al., 2018).

> *"(. . .) Eye movement reflects the human thought processes; so the observer's thought may be followed to some extent from records of eye movement (the thought accompanying the examination of the particular object). It is easy to determine from these records which elements attract the observer's eye (and, consequently, his thought), in what order, and how often." (*Yarbus, 1967*, p. 190)*

Until now, human eye-positions receive much attention to gain objective insights into how consumers sample information, make decisions under different task-instructions or mind-wander, where the slightest change in gaze allocation reflects a shift in information-prioritization (Yarbus, 1967; Baron-Cohen et al., 1997; Najemnik and Geisler, 2005, 2009; Castelhano et al., 2009; Tatler et al., 2010; Morii and Sakagami, 2015; Boisvert and Bruce, 2016).

Principally, in order to find the optimal outcome, decisional processes such as (i) assessment and formation of preferences, (ii) selection and execution of action(s), (iii) experiencing the outcome, are all orchestrated in human brain systems. A combination of eye-tracking methodology and decision-making (high-level information processing) paradigms can result in understanding one's cognitive and affective mental state and explain reactions in a real-world context (Bogacz et al., 2006; Bogacz, 2007; Paulus, 2007; Cocker et al., 2012). Moreover, there is growing evidence that decision-making and homeostatic processing are inextricably linked, and that cognitive impairments (e.g., disturbances of memory, attention deficits and difficulty in problem-solving) among clinical populations cannot be understood without the reference to the performance of independent living skills (Brand et al., 2005; Paulus, 2007; Bachman et al., 2010).

Since eye-tracking instruments objectively reflect action selection, based on decision maker's attention, information processing capabilities, and motivated cognition processes (Deubel and Schneider, 1996; Ernst and Paulus, 2005; Simion and Shimojo, 2006; Glaholt and Reingold, 2009; Markkula, 2015; van der Laan et al., 2015; Gerbella et al., 2017; Onuma et al., 2017; Wolf et al., 2018, 2019), it should not be overlooked that relatively cost-effective and non-invasive eye-tracking devices are becoming vital instruments exposing the mechanism of cognitive and perceptual disturbances among clinical populations (Tseng et al., 2013; Türkan et al., 2016; Sawada et al., 2017; Morita et al., 2020; Wolf et al., 2021).

VISIBLE IMPAIRMENTS IN INFORMATION PROCESSING

Longitudinal persistence of exhibited deficits in intellectual functioning, i.e., attention, memory and executive function, suggest that information processing abnormalities are related to the core of a vast number of mental disorders. For example, Autism spectrum disorder (ASD) adults and children have been reported to spend less time looking at silent features of face stimuli (mouth, nose, and eyes regions) and

more time at non-social stimuli than healthy controls (HC) (Corden et al., 2008; Frazier et al., 2016). Furthermore, while viewing video clips, young ASD adults have been reported to spend more time gazing at objects (instead of people). These observations support a poorer social adjustment among ASD patients, where by fixating on non-social stimuli, ASD patients are predestinated to miss socially important cues (Klin et al., 2002).

In the context of eating disorder group, it has been suggested that the majority of studies investigated the attentional bias toward disorder-relevant stimuli, which was based on reaction times that measured attention indirectly, i.e., without revealing its time course (Shafran et al., 2007; Sperling et al., 2017; Kerr-Gaffney et al., 2019). With the use of eye-tracking technology, however, it is possible to measure attention directly, where for example measurements of the overall viewing time, scan-path length, number of saccades, and the differentiation between early and late stages of attentional processing are achievable (Giel et al., 2011). Jansen and colleagues found that participants with eating disorders, when viewing photos of their own bodies, focused less on their self-defined *beautiful* body parts and more on their *ugly* parts than the HC group did (i.e., inspection of the ugly body parts was given priority). However, when viewing pictures of others, the eating disorder group showed the opposite pattern (Jansen et al., 2005).

Recent studies, which investigated food and non-food stimuli under free-viewing task, report that both groups: binge eating disorder (BED) and HC, tend to fixate their gaze longer on non-food images. However, when comparing the total viewing time for food pictures, those with BED visually attended to them for a longer time duration than HC (Schag et al., 2013; Schmidt et al., 2016; Sperling et al., 2017). Interestingly, Baldowski and his team reports that individuals with night eating syndrome show an initial orienting bias toward food stimuli over non-food images (Baldofski et al., 2018).

It has been reported that individuals with social anxiety disorder show a quicker attentional disengagement from the eyes, in line with the vigilance-avoidance theory of attention (Horley et al., 2003, 2004). In two experiments reported by Boll and colleagues, patients with social phobia and HC were compared regarding their gaze behavior toward displayed photos of human faces (Boll et al., 2016). The results from performed paradigms (emotion classification paradigm and gaze-cueing paradigm) indicate that in comparison to HC, patients reflexively orient their attention toward the eyes of emotional faces in the emotion classification paradigm. This initial hypervigilance for the eye region can be observed at very early attentional stages and persists for a longer duration of time. Moreover, Boll and colleagues reported that individuals with social phobia exhibit a delayed attentional orienting into the direction of eye gaze. This observation may suggest a differential time course of eye gaze processing in individuals with social phobia and HC.

The fundamental issue of eye behavior reflecting attention and its deficits (Yarbus, 1967; Braff, 1993; Rommelse et al., 2008; DeAngelus and Pelz, 2009; Borji and Itti, 2014) attracts the scientific community as a measurable indicator of one's sequence of thoughts (Bird et al., 2012; Thakkar et al., 2018; Wolf et al., 2018, 2019). Therefore, we put forward the statement that eye-movement measurements gathered from visual information-processing paradigms are already supporting the development of integrated eye movement scores (kindly refer to Morita et al., 2017; Obyedkov et al., 2019).

Information processing deficits are an important area of investigation focusing on identifying the key features of life-impoverishing disorders that may allow efficient early intervention and support the discovery of preventive treatments. Moreover, for the reason that almost every area of the brain plays a role related to the ocular motor control system, the implementation of eye-tracking technology to cognitively informative tasks, has proven to be a fruitful approach in uncovering human information processes (Jarodzka et al., 2010; Glaholt and Reingold, 2011; Lai et al., 2013; Pärnamets et al., 2015; Roberts et al., 2018). However, mental health professionals avoid capturing eye-data through tasks that may have "too unusual demands" or could be labeled as "too complicated." This may explain why real-life oriented decision-making paradigms are hesitantly used to discover the mechanisms that underlie non-optimal (non-homeostatic) behavior among clinical populations.

Loss of Social Autonomy Due to Cognitive Impairments

Unequivocally, scientists need to be thoughtful about patients, who suffer from psychiatric disorders such as schizotypal personality disorder (STPD), schizophrenia (SZ), major depressive disorder (MDD), bipolar disorder (BD), and ASD (which entails a spectrum of disorders, namely autism, Asperger's disorder, and pervasive developmental disorder-not otherwise specified, PDD-NOS). While experiencing various cognitive impairments, clinical populations may face disinterest in social contact, discomfort in interpersonal situations, decreased ability to feel pleasure (physical anhedonia), and/or diminished experience of reward (Cocker et al., 2012). Notably, some patients are being unable to independently execute instrumental activities of daily living, e.g., managing money, commuting, preparing meals, shopping. For example, BP patients may excessively involve in activities with high potential for painful consequences (e.g., engaging in unrestrained buying sprees or impulsive business investments), being therefore at a higher risk of gambling and compulsive spending. Overall, clinical populations are either omitted as decision-makers, facing a loss of social autonomy (Mottron et al., 2006; Sablier et al., 2009), or taken advantage of due to the inability to control their consumption practices (Jones et al., 2015).

Therefore, it is crucial to identify the relationship between cognitive deficits and specific activities among people with psychiatric diseases. In order to do so, few research groups considered designing experimental paradigms to resemble a real-life tasks (Hamera and Brown, 2000; Rempfer et al., 2003; Zayat et al., 2011; Laloyaux et al., 2012, 2013). In 2002 Hamera and colleagues conducted a grocery shopping skill test, measuring the performance of shopping ability, which requires complex cognitive skills (Hamera et al., 2002). In this particular study, the performance of two groups has been compared, i.e., individuals

with significant cognitive impairments (SZ and BD patients) and a normative population of HC. In particular, the researchers reported that individuals with SZ and BD took longer time in task completion. Besides, the group with significant cognitive impairments showed higher redundancy in performing the shopping task than the healthy control group.

Moreover, in another shopping task investigating buying performance, where participants were required to purchase grocery store items from a shopping list, Laloyaux et al. (2013) significantly differentiated BD patients from HC for two variables, namely (1) the total time to complete the shopping and (2) the mean time spent to consult the grocery list. The same research group reported that the performance of a shopping task correlated significantly with individual's cognitive functioning (i.e., processing speed, verbal episodic memory, planning, and cognitive flexibility) and with clinical variables, such as duration of illness and functioning in an authentic life context (Laloyaux et al., 2013).

Described examples provide evidences of reliability and validity of context-based tests related to purchase intentions and shopping performance measurement (Manee, 1997; Hamera and Brown, 2000; Rempfer et al., 2003). Also, current advances in eye-tracking technology and data analysis (McGrath et al., 2018; Zommara et al., 2018) allow the scientific community to conduct follow-up experiments (and/or build new ones) in order to provide a deeper knowledge concerning how cognitive deficits impact clinical population in a real-world functioning context.

Future decision-making paradigms may provide promising reaction-derived data, disclosing repressed feelings, unconscious reactions/habits. This may help to clarify the basis of high heritability, associated with psychiatric disorders, and promoting transdiagnostic research. Moreover, it may refine the diagnosis procedure, which is highly challenging, especially in heterogeneous disorders such as schizophrenia (see Koychev et al., 2011). The implementation of eye-tracking methodology appears to be a straightforward undertaking. Through the detected position of the viewer's pupil, gaze points can be easily determined and further analyzed with the use of mathematical algorithms. Hence, the implementation of eye-tracking technology fits perfectly the aim to non-invasively disclose valuable information regarding individual's behavior, which cannot be as precisely discovered through written nor verbal approaches (Riby and Hancock, 2008; Dewhurst et al., 2012; Chawarska et al., 2013; Maruta et al., 2014; Diwakar et al., 2015; Fujioka et al., 2016; Crawford et al., 2017; Oyama et al., 2019).

Revealing One's Moment-by-Moment Focus of Attention

It has been stated that eye-movement technology provides a moment-by-moment measure of the focus of attention and reveals what cognitive strategies (interplay of top-down and bottom-up processing) are employed to solve a particular task (Eckstein et al., 2017). In the past years, experts have used *pupil dilation* data to reveal for example the subjective difficulty of cognitive tasks and their intensity (mental effort). The choice of this parameter has been supported with a common knowledge that pupil dilation provides a window into the brain's locus coeruleus-norepinephrine (LC-NE) system (Laeng et al., 2012; Burkhouse et al., 2015; Chevalier et al., 2015; Bast et al., 2020). Neurophysiological findings provide significant insights to the meaning of pupillary responses for mental activity. Given that pupillary responses can be easily measured in a non-invasive manner in each stage of life, and can occur in the absence of conscious processes, they constitute a promising tool for the study of preverbal (e.g., infants) and non-verbal participants.

Furthermore, *spontaneous eyeblink rate* (sEBR), as a proxy of dopaminergic activity (Jongkees and Colzato, 2016; Eckstein et al., 2017; Gotlieb et al., 2021) has been used to study cognition, interest, and predict stress levels in humans (Chermahini and Hommel, 2010; DeYoung, 2013). Since spontaneous blinks are uniquely different from voluntary and reflexive eye-blinks, they represent a range of information processing functions spanning attention and working memory (Müller et al., 2007; Schumacher et al., 2013; Groman et al., 2014). For example, humans subjected to stressful stimuli (through social and emotional recollection tests) were reported to exhibit an increase in spontaneous blink rate. Several studies reported that increased eyeblink rate reflected an increasing level of fatigue (Beatty, 1982; Borghini et al., 2014; Gergelyfi et al., 2015). On the other hand, spontaneous blink rate has been found to decrease when the subjects are most attentive in performing demanding tasks associated with memory operations and attentive behaviors (see Hirokawa et al., 2004; Brefczynski-Lewis et al., 2011; Paprocki and Lenskiy, 2017). Moreover, eye blink parameters enable to investigate the influence of specific stressors that initiate emotional anxiety or neurological levels of arousal (van de Groep et al., 2017).

Area of interest (AOI) that is not categorized as a gaze metric by itself but defines regions by which gaze metrics may be calculated, has been reported to help in studying reasoning on account of integrating several pieces of information and reflecting the process of comparing specific locations of presented stimuli (Dewhurst et al., 2012; Hunter et al., 2020). Recently, to assess cognitive function using high-performance eye-tracking technology, Oyama and colleagues developed a novel cognitive assessment tool (Oyama et al., 2019), which has been reported as brief and practical since the subject simply views a series of short movies and pictures displayed on a monitor. In each task, multiple stimuli, including the target image (correct answer) and non-target images (distractors), are presented on the monitor. The subject is instructed to identify and focus her gaze on the correct answer. The AOI is set on the correct answer, and the cognitive score is determined from the eye-movement data by measuring the fixation time on the region of the correct answer (kindly refer to **Figure 1**). Oyama and colleagues concluded that the cognitive score correlated well with the scores from neuropsychological tests, showing an outstanding diagnostic performance in detecting patients with mild cognitive impairment (MCI) and dementia (Oyama et al., 2019).

Next, *scanning patterns* have been widely covered in the scientific literature, giving insight into one's exploration behavior, directly related to the nature of the task (Kojima et al., 1992;

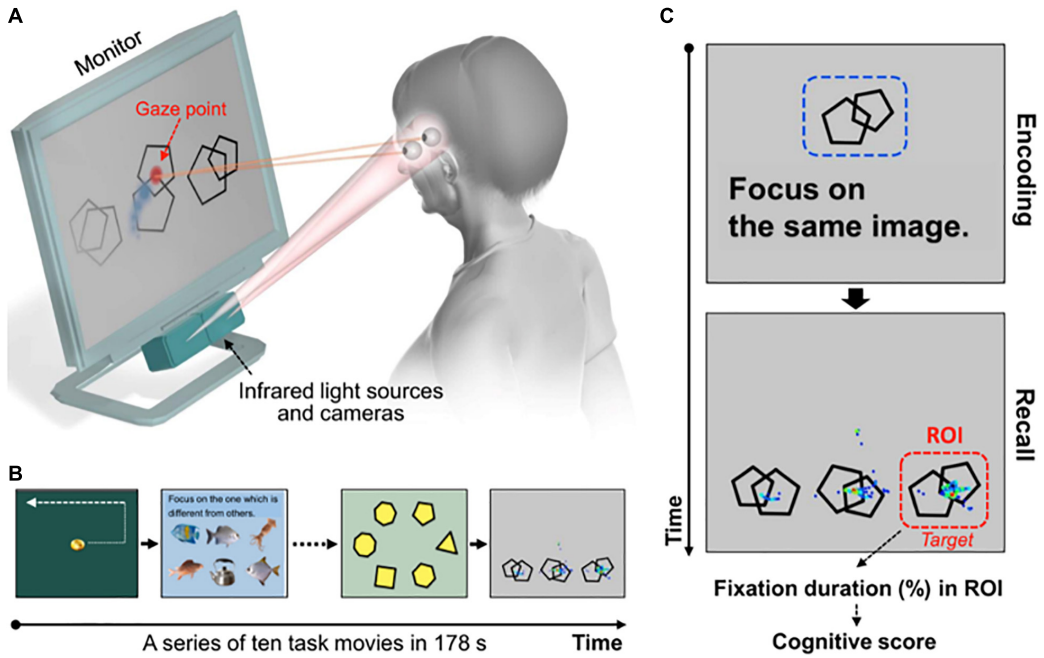

FIGURE 1 | Rapid cognitive assessment using an eye-tracking system and tasks, obtained from Oyama et al. (2019). **(A)** Participant's gaze points are recorded. **(B)** Ten tasks are displayed one by one on the monitor. **(C)** An example of a working memory task and representative gaze plots with a duration-based heatmap obtained from a control subject. Gaze plots represent the location and time spent looking at the objects. A cue object (e.g., a set of double pentagons) is presented for 10 s (*encoding phase*), followed by three distinct objects with the same one as the cue object (right bottom on the monitor, *target*). In the next phase (*recall*) the participant is asked to remember and gaze at the target object. Fixation duration within the region of interest (ROI) set on the target object is used to obtain the cognitive score.

Bestelmeyer et al., 2006; Castelhano et al., 2009; Risko et al., 2012; Sprenger et al., 2013; Helo et al., 2014; Dowiasch et al., 2016; Yazdan-Shahmorad et al., 2020). Recently, exercising the differences between subjects' visual scanning patterns Chung et al. (2018) could disambiguate bipolar and unipolar patients with high accuracy (Chung et al., 2018). Since misdiagnosing BD as MDD is relatively common, the introduction of biomarkers to improve diagnostic accuracy, in the earliest course of the illness, plays an important role in the clinical field. With the use of recurrent neural network (RNN), the differences between fixation sequences provided a classifier that disambiguated BD from MDD patients with a remarkably high accuracy.

Finally, *gaze duration* (viewing time) that reflects (i) the quality of the available visual information, (ii) the contextual background with which objects can be recognized and understood, (iii) individual goals of the observer, and (iv) information-search strategies (Underwood et al., 2008; Najemnik and Geisler, 2009; Schotter et al., 2010; Foulsham and Kingstone, 2011, 2013; Pierce et al., 2016; Roux et al., 2016; Saito et al., 2017) has been pointed out to be a useful index of the extent of information processing (Bird et al., 2012; Wolf et al., 2018, 2019). Moreover, Wolf and colleagues suggested that uncertainty can prolong the effort of visual processing (Wolf et al., 2019).

Taken together, data commonly captured by eye-trackers such as (i) eye opening and closure (e.g., blink duration, blink frequency), (ii) gaze parameters (e.g., number of fixations, saccades, viewing time), (iii) pupil properties (e.g., pupil dilation, pupil size), give valuable insights into how a viewer (un)consciously filters information, undertakes the decision strategy, and determines the subjective hierarchy of perception. Moreover, human eye-movements have illustrated valuable insights regarding the information processing patterns, translated into attentional landscapes, fixation sequences, or heat maps, and served as measurable outputs of the extent of undergoing cognitive processes (Bird et al., 2012; Pärnamets et al., 2016; Zommara et al., 2018). In conclusion, recordings of the eye-movements provide answers to important questions of when and how visual information is being captured and processed in scientifically controlled as well as ecologically valid environments (for outstanding work on implementing ecologically valid paradigms to understand psychiatric disorders, refer to Scholl and Klein-Flügge, 2018).

Thanks to the neuroscientific tools, neurological representations of the brain and neural activity can be generated. The purpose is straightforward, to have real-time insights into specific responses in the brain and nervous system, resulting from the presentation of a stimulus (Lim, 2018). Especially, eye-tracking technique provides a relatively low-cost and sensitive indicator for initial orienting, shift, and maintenance of attention (Caseras et al., 2007; Kou et al., 2016; Wolf et al., 2021). Since eye-movements provide realistic evidence of where participants are likely to look at Bird et al. (2012); Morii and Sakagami (2015); van der Laan et al. (2015); Wolf et al. (2018, 2019), this might be a valid reason why some research

groups choose precisely the eye-tracking technique to study attentional biases among individuals with body dysmorphic disorder (BDD) (Kou et al., 2016), which is characterized by repetitive behaviors and/or mental acts occurring in response to preoccupations with perceived defects or flaws in physical appearance (American Psychiatric Association, 2013). For instance, to explore attentional bias toward body-related pictures among females with weight dissatisfaction Gao and colleagues employed the eye-movement technique. The researchers reported an orienting-maintenance pattern of attention toward fatness-related pictures among weight-dissatisfied women, implying that this group preferentially attended to body-related/fatness-related stimuli (Gao et al., 2012). In addition, results presented by Greenberg and her team also suggest that individuals with BDD "*overfocus on negative attributes*" (Greenberg et al., 2014). "*While current treatments generally show moderate effectiveness in the short-term, those with BDD can have high relapse rates, as they still "see" their flaws or defects*" (Beilharz et al., 2018). Therefore, elucidating the role of attention (e.g., negative/positive bias) may help to identify risk and maintenance factors among BDD patients (Grocholewski et al., 2012; Greenberg et al., 2014; Kollei et al., 2017). For example, in 2018, Beilharz and her colleagues proposed a visual training program (encompassing basic visual processing, face and emotion recognition, and self-perception), which has been designed to remediate visual abnormalities and reduce symptom severity among individuals with BDD (Beilharz et al., 2018).

In another elegant experiment, supported with the eye-tracking methodology, Toh and colleagues investigated facial affect recognition in BDD and obsessive-compulsive disorder patients. Relative to OCD patients and HCs, patients with BDD demonstrated (i) significantly poorer facial affect perception (misidentifying emotional expressions as angry, i.e., BDD participants misinterpreted more faces as angry in comparison to OCD patients and HCs); (ii) atypical scanning strategy characterized by significantly more blinks, fewer but longer fixations, and less visual attention devoted to the salient facial features (Toh et al., 2015). With this in mind, in the future, researchers may consider developing interventions that will reduce distress for individuals with high body image dissatisfaction (for future directions for positive body image research refer to Halliwell, 2015).

The scientific community is already witnessing a considerable rise in gaze metrics models targeting to unveil one's values (goals, tradeoffs, objectives) and beliefs (facts, opinions, uncertainties), tapping into unconscious processes governed by individuals' internal state (homeostasis). Clinicians have actively grasped the technological advances in vision science, demonstrating characteristic eye-movement distortions in patients with psychiatric disorders or individuals being potentially at risk of them (kindly refer to an illustrative example in **Figure 2**). An extensive number of clinical findings reported abnormal gaze parameters among clinical populations (e.g., prolongation of saccadic latency, abnormal smooth pursuit, ocular drift (glissades), square wave jerks, and impaired vestibulo-ocular reflex) (see Silverstein et al., 2015).

A great number of the clinical results (especially in the schizophrenia research domain) refers to now-classic paradigms, i.e., *smooth pursuit test* (where participants are required to track a moving target with their gaze) and *fixation stability test* (where participants are asked to maintain their gaze on a defined fixation point). Both paradigms are known for their overwhelming evidence in the scientific literature (Holzman et al., 1973, 1974, 1980; Holzman, 1985; Koychev et al., 2011), and are highly important to study attentional deficits. For example, it has been reported that SZ patients (and their biological family members) perform the smooth pursuit test inaccurately. Moreover, gaze maintenance on a single target (fixation) is unsteady among SZ patients. Besides, their first-degree relatives have been reported to be deficient in fixation maintenance as well (Benson et al., 2012).

To disclose one's exploratory eye movement behavior, free-viewing paradigms are also widely applied in clinical research domain (Kogata and Iidaka, 2018; van Renswoude et al., 2018; Lakhlifi et al., 2020) (**Figure 3**). Abnormalities in visual scanning have been reported to afford an impressive accuracy of specificity and sensitivity. First, by demonstrating usefulness in quantitative scoring and sensitive detection of cognitive impairments and next, by tapping the subtype of mental illness (Beedie et al., 2011; Li et al., 2016, 2020a; Oyama et al., 2019).

Although now-classic (i.e., smooth pursuit and fixation stability) and free-viewing tests are highly visible in clinical experiments as routine screenings, simple and sufficiently short real-life decision-making paradigms supported with an eye-tracking technology, are scarcely being applied in a form of a screening tool for the early detection of cognitive decline (and related with it disorders). It is not in the scope of our article to list the benefits of an early diagnosis; however, we find it crucial to mention that it can give individuals at risk the opportunity to benefit from symptomatic treatments (Barnett et al., 2014, cited in Oyama et al., 2019). Additionally, the early detection of cognitive impairments can increase the efficiency of patient recruitment for clinical trials of drug development, which has shifted to focus on the early stage of some diseases (Graham et al., 2017; Carl et al., 2020).

Hence, to address the investigation on how clinical populations approach real-life functioning tasks, new research questions require analysis of decision-making paradigms that may provide informative attentional scan-paths and explorative eye-movements, beyond the quantification of fixations and saccades (Wolf et al., 2021). Furthermore, since decision-making paradigms fundamentally relate to the individual's homeostatic processing, it seems straightforward to actively translate them into clinically performed experiments, supported with non-invasive eye-tracking devices.

TRANSLATIONAL PRACTICE

Reflecting cognitive states of the viewer, eye-movement measurements have been reported to find potential application in the translational clinical practices. For instance, in the form of biomarkers, they may be used to identify individuals at risk, allowing efficient management of the process of early

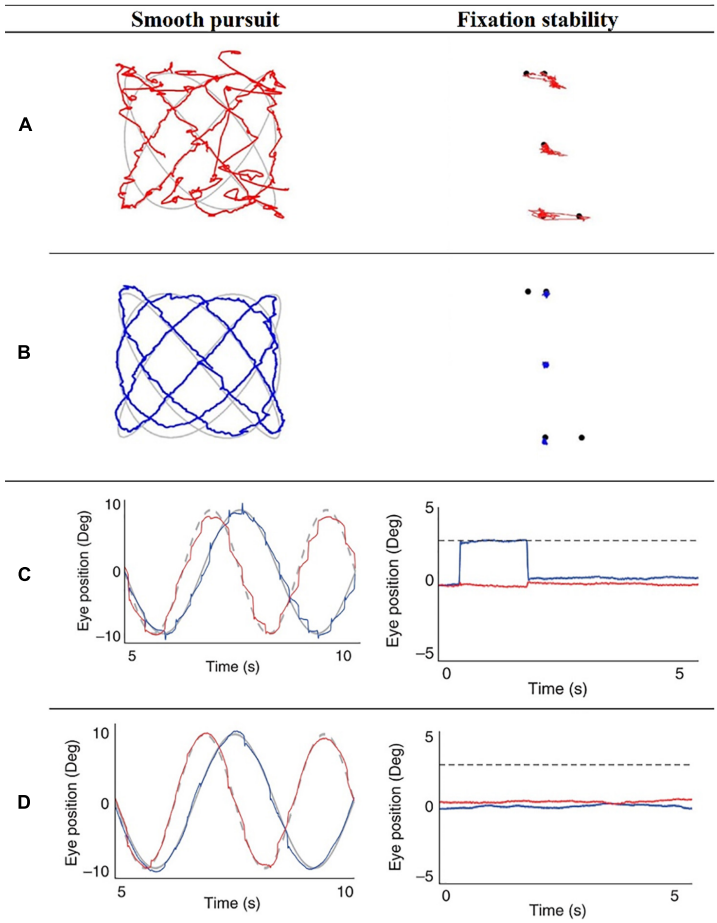

FIGURE 2 | Illustrative eye-movement recordings of pursuit and fixation stability tests of schizophrenia (SZ) patients and healthy controls (HC), obtained from Benson et al. (2012) and Morita et al. (2017). Importantly, the reader should bear in mind that not every participant will exhibit "normal/abnormal" eye-movements on every trial nor on each task. Illustrative Lissajous pursuit and fixation stability tests of SZ patient **(A)** and HC **(B)**, obtained from Benson et al. (2012). Representative eye-movement recordings of a patient with SZ **(C)** and one HC **(D)**, during the smooth pursuit eye movement test (fast Lissajous paradigm) and the fixation stability test (far distractor paradigm), obtained from Morita et al. (2017).

intervention. Therefore, in this part or the article, we anticipate how the knowledge from decision-making (information processing) paradigms that implement eye-tracking technology, can provide a beneficial platform for economists, psychiatrists, neurologists, and social and clinical psychologists to develop a common language for studying context-laden behavior in psychiatric disorders (Paulus, 2007). Such an approach may broaden current knowledge of mechanisms, which underlie illnesses and maladies (e.g., eating disorder, obsessive-compulsive personality disorder, pathological gambling) characterized by individuals' inability to control their consumption practices (Javor et al., 2013).

Misconception of Integrating Neuromarketing Into Clinical Experiments

It is important to solve the misconception of integrating neuromarketing into clinical experiments. In neuromarketing research, physiological and neuroscientific methods are being actively used to study consumer behavior to better understand the underlying neurobiology of psychological phenomena of decision-making processes, as well as to provide a more comprehensive assessment of the efficacy of marketing strategies such as advertising campaign planning or product positioning (for an excellent description on the most pertinent neuroscientific methods recommended for neuromarketing, kindly refer to Lim, 2018). Thus, neuromarketing may enclose a two-way interpretation of potential application: (*1*). *scientific*, focusing on consumer's decision-making (action selection, from a set of available options) and (*2*). *commercial (for-profit)*, requiring scientific findings in order to establish the most profitable business strategies for consumers to purchase a certain product (Gidlöf et al., 2013, 2017; for a comprehensive debate on neuromarketing and consumer neuroscience, see Javor et al., 2013).

In recent years, due to sensational journalism, concerns related to subliminal advertising as a form of external

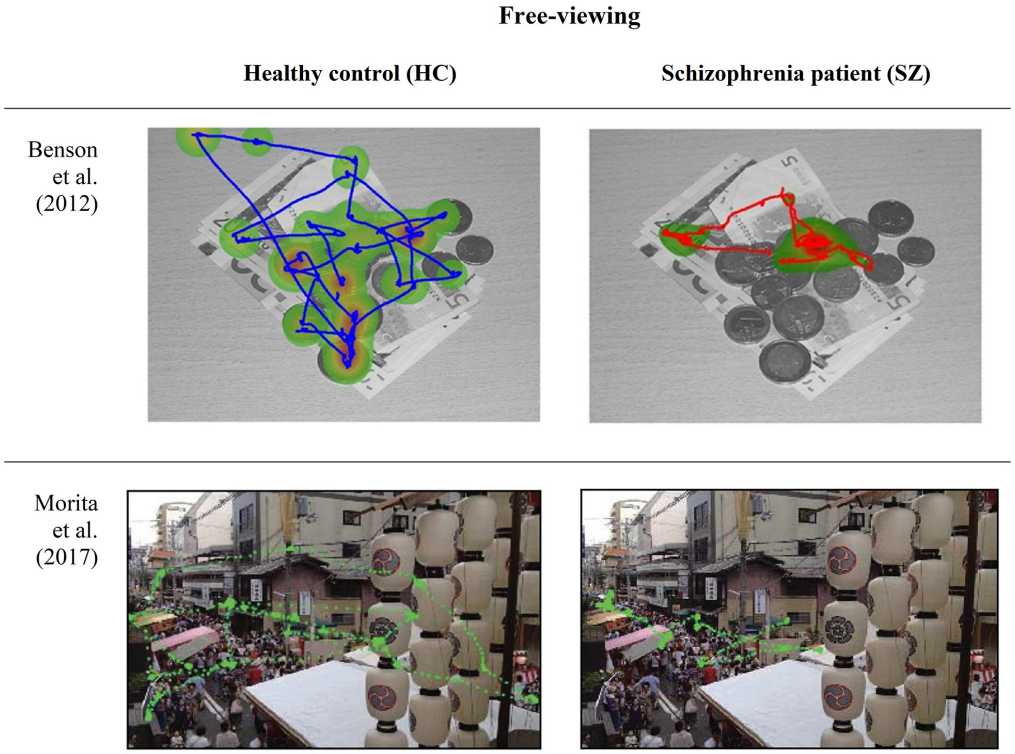

FIGURE 3 | Eye-movement recordings of a patients with schizophrenia (SZ) and healthy controls (HC) during a free-viewing paradigm, obtained from Benson et al. (2012) and Morita et al. (2017).

purchase manipulations have emerged (for an insightful discussion on "Consumer Surveillance and Ethical Concerns" see Nemorin and Gandy, 2017). These misconceptions (i.e., scientifically unsupported controversial anecdotes) influence the academic efficacy and practical utility of neuroscientific measurement techniques in understanding the human decision-making processes (Pop et al., 2014; Thomas et al., 2016; Lim, 2018). Although Pop et al. (2014) clearly stated that *"One of the most important challenges for companies who offer neuromarketing services is to stick to ethical principles when performing the investigations. This is an obligation they have both toward the beneficiaries – the companies providing products or services – and toward their consumers as well (. . .),"* the dispute between the advocates and critics of neuromarketing remains present until today (Foscht and Swoboda, 2011; Pop et al., 2014).

Not to distract this highly important discussion, consumer neuroscience (that enriches understanding of consumer psychology and behavior) and neuroeconomics (that refers to sensemaking of economic problems through the analysis of neural correlates of decision making) should be studied, among healthy controls and clinical populations (Rahman et al., 2001; Nemorin and Gandy, 2017; Wolf et al., 2021). The decisive advantage is that with the support of neuromarketing and its neuroscientific methods the *reasons behind individuals' decisions* can be investigated (Foscht and Swoboda, 2011).

Translational practices (of behavioral economics frameworks) have been mentioned to be useful to evaluate the dysregulation of reward-oriented behavior (Kobayashi et al., 2019). For example, patients with orbitofrontal cortex (OFC) damage have been reported to make poor decisions about day-to-day activities and engage in risk-taking behaviors (Bechara et al., 1994; Shiv et al., 2005; Floden et al., 2008), which may have negative consequences for their wellbeing and overall mental health (Rahman et al., 2001). Therefore, carrying out decision-making paradigms may help licensed therapists to validate the therapy directed toward patients with impulsive-compulsive disorders, such as for example pathological gamblers (frequently reported among individuals with Parkinson's disease, frontotemporal dementia, and Huntington's disease) and compulsive buyers (characterized with impulse control disorder, which co-occurs with depression) (De Marchi et al., 1998; Javor et al., 2013; Kalkhoven et al., 2014). In essence, neuromarketing studies, conducted in accordance with the Ethical Code of Conduct issued by the Neuromarketing Science and Business Association, would be of significant benefit to the general social progress (Pop et al., 2014).

Eye-Trackers Offset Traditional Self-Reporting Assessments

We also need to address that in clinical research, mental disorders are mainly diagnosed through observations made by highly specialized psychiatrists that are based on a patient's overall behavior and self-reports. This means that for a patient to receive

a diagnosis of a mental disorder, standardized criteria such as alterations in behavioral and cognitive development, laid out by the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association, 2013), must be visible to the clinician. However, similarly as in marketing research, traditionally used subjective tools (e.g., rating scales that allow respondents to provide nuanced answers, questionnaires, and tests) are characterized with well-known limitations (Connors et al., 2016; Bell et al., 2018), lacking credibility due to self-report biases that are present when responding to sensitive questions related to addictive behaviors and criminal or sexual experiences (Tourangeau and Yan, 2007). By offsetting weaknesses associated with traditional self-reporting assessments that are usually designed for one disorder or limited in their examination of phenomenological features, eye-tracking generates considerable interest in terms of consumer research not as a complementary but as a standing-alone technology, revealing one's moment-by-moment internal state (homeostasis) (Ernst and Paulus, 2005; Paulus, 2007; Wolf et al., 2021).

Not restricted to economic disciplines only, the eye-tracking methodology represents a category of interdisciplinary research instrumentation that has successfully intermingled with various research questions/tasks and exercised human eye-behavior with numerous stimuli categories (geometrical figures, computerized and real human faces, naturalistic food images, haptic and pictorial illusions as well as advertisement videos). These compelling arguments stand for eye-tracking technology being actively used in interdisciplinary laboratories, generating behavioral experimental paradigms that integrate contributions from psychology, philosophy, and affective and computer sciences (Borji et al., 2013; Spinks and Mortimer, 2016; Vu et al., 2016; Gidlöf et al., 2017; Wolf et al., 2018; Zommara et al., 2018; Vriens et al., 2020).

Future paradigms, which incorporate a decisional context (homeostatic regulation), may generate findings of significant importance to all behavioral sciences (including medical sciences such as neurology and psychiatry). Although the current trend in clinical research does not aim to replace the diagnosis criteria that rely on clinical observations and self-report, recent studies started to test the possibility of gaze metrics to distinguish patients suffering from mental disorders from healthy participants, hoping for a successful diagnosing tool, and those potentially at risk, aiming for an early intervention chance (Benson et al., 2012).

Bridging decision-making science with medical science may support clinical interventions and contribute to health services research agenda, to improve population health outcomes. Ideally, scientists develop cognitively informative paradigms, aiming to understand behavior among HC, which can be then applied to individuals suffering from mental illnesses, in order to identify biomarkers that point to one's brain integrity (mechanism of information processing that requires a synchronized activity of lower and higher-order brain structures). Clinical paradigms, however, tend not to implement higher-order cognitive components related to decision-making paradigms, based on neurobiologically informed economic theories and mathematical choice psychology. Thus, a gap is being created where the translational approach of decision-making paradigms, that involves testing of the potential biomarkers in clinical trials, is scarcely reached. If not cued by cognitive scientists, eye-tracking technology may remain a theoretical recommendation for clinical practices (Wolf et al., 2021).

DISCUSSION

To capture and investigate an interplay between cognition (and its deficits) and eye-movements, information-processing paradigms that reveal one's gaze-patterns are needed. Following the global trend of the so-called *digital pharma* (or *beyond the pill*) strategy (Rutkowski et al., 2020) there is a need for technologies that support early diagnostics for cognitive interventions and monitor individual's mental wellbeing. In our opinion, eye-movement measurements come in as a relatively low-cost measurable indicator (biomarker) of one's homeostatic (mental) state. It has been reported that cognitive dysfunctions detected through gaze analysis may indicate or even predict mental disease processes (Fujioka et al., 2016; Almubark et al., 2020; Wolf et al., 2021). Moreover, studies of significant importance have produced preliminary findings that show that gaze-metrics parameters such as fixations (their location, number and duration), saccades (their number and amplitudes) and the scan-path length, are abnormal in a great number of neurological diseases (Beedie et al., 2011; Benson et al., 2012; Türkan et al., 2016; Li et al., 2020b; Morita et al., 2020).

However, cognitively informative paradigms are needed to draw further implications for medical experts and clarify aspects of visual impairments that manifest among clinical populations. Such paradigms may provide additional knowledge regarding attention, engagement and memory retention, all together combined as the foundation of an undertaken decision (Scholl and Klein-Flügge, 2018). When taking into consideration that approximately 95% of human decision-making processes happen at the subconscious level (Zaltman, 2003; Pop et al., 2014; Nyoni and Bonga, 2017), neuroscience opens the possibility of getting closer to the invisible part of neuronal connections, overcoming limitations related to self-reported methodologies (Connors et al., 2016; Bell et al., 2018).

Since numerous clinical works call for an etiology-based diagnosis (i.e., to understand the brain processes of individuals, who suffer from mental disorders), the development of reliable biomarkers (improving the diagnosis, identifying at-risk-individuals, and providing novel targets for therapeutic interventions), is not only in highly demand but it is the main purpose of modern clinical research (Kim et al., 2011; Daglas et al., 2015; Yahata et al., 2017; Wolf et al., 2021).

Eye-behavior tests that discriminate clinical cases from control subjects, have mounted in recent years. Shiino and colleagues reported significant differences between subjects with ASD and SZ in 5 selected eye-movement characteristics that were obtained from free-viewing and smooth pursuit tests (Shiino et al., 2020). Some other research groups modernized the clinical development process by integrating digital methods, based on machine learning (ML) approach (Benson et al., 2012; Tseng et al., 2013). For example, Tseng et al. (2013) extracted quantitative features from gaze data with the support of automated ML. Following

this procedure, the authors were able to differentiate patients with attention deficit hyperactivity disorder (ADHD) and fetal alcohol spectrum disorder (FASD) with overlapping behavioral phenotypes from age-matched healthy participants (Tseng et al., 2013). Therefore, ML techniques extracting disorder-specific features for an automatic classification should be considered in prospective clinical applications (Huys et al., 2016; Yahata et al., 2017).

It is important to mention that eye-trackers can be utilized as a new intervention training tool for exposure therapies or attention redirection training. In the context of obsessive-compulsive disorder (OCD), Bradley and colleagues reported that eye-tracking, attentional control, and severity of attentional bias can indicate the therapeutic progress of implemented treatment plan, e.g., exposure response prevention — ERP (Bradley et al., 2016). Therefore, monitoring obsessions, compulsions, and attentional biases in a real-life context may determine therapy outcomes more accurately.

An implementation of real-life inspired paradigms related to general as well as social cognitive impairments will allow a better understanding of the homeostatic processing abnormalities among clinical populations (Ernst and Paulus, 2005; Paulus, 2007; Billeke and Aboitiz, 2013). At the same time, the support of eye-tracking technology will help to objectively illustrate and measure how and when information processing goes away from the expected course. For comprehensive and interdisciplinary models to be built in the future, experimental paradigms resembling real-life activities should be conducted, to have a clearer and disorder-specific picture of how converging as well as diverging tasks are processed inside patient's mind and interpreted by her eyes.

Limitations

Since gaze metrics, gathered from visual information processing tasks, have recently started to support the development of non-invasive and relatively inexpensive biological markers in the clinical research domain, the presented article aimed to draw readers attention to one particular neuroscientific tool, namely the eye-tracking technology. Other neuroscientific methods were omitted due to the intentionally narrowed scope of this article.

Presented work is likely generalizable to journal articles and systematic reviews acquired through the Kyushu University Open Access Policy. Furthermore, to refrain from any unintended bias (caused by the authors' research background), while addressing the aim of the perspective article, AW and KU have included a great number of articles, which relate to now-classic and modern clinical studies. The protocol was drafted using PRISMA guidelines, revised by the authors and lab members to solicit additional feedback. Articles published between 2010 and 2020, reporting cognitive impairments or abnormal eye-movements patterns among clinical populations, were identified by Mendeley and PubMed searches (search terms were: "eye-tracking", "shopping task," "cognitive deficits," "clinical application," and "cognitive impairments"). Reference lists of all in-scope articles have been additionally screened for relevant publications. Notably, to interlock the trend of decision-making paradigms, non-clinical open access articles were included in this work as well.

Finally, despite the absence of empirical data, best efforts have been undertaken to produce an objective, academic article that refrains from scientifically unsupported sensational claims concerning neuromarketing and its neuroscientific methods. It is hoped that the gathered examples will propel a greater interest and insightful research in consumer behavior and neuroeconomics, among individuals with mental disorders.

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

AW wrote the manuscript with a critical revision from KU. Both authors contributed to the article and approved the submitted version.

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Meaning of Gaze Behaviors in Individuals' Perception and Interpretation of Commercial Interior Environments: An Experimental Phenomenology Approach Involving Eye-Tracking

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A critical question in interior design is how multisensory information is integrated into occupant perception and interpretation of the environmental contexts and meanings. Although there have been efforts to identify and theorize visual perception of interior factors or features (e.g., colors, fixtures, and signs), the hidden meanings behind visual attention and behaviors have been neglected in interior design research. This experimental phenomenological study investigates the impact of auditory stimuli on the gaze behaviors of individuals and the hidden meanings of their audio-visual perceptions of commercial interiors. Implementing eye-tracking and open-ended interviews, this study explored how the neurophysiological and phenomenological methods in complementary can serve for interior design research on the meaning of gaze behaviors. The study used a convenience sample of 26 participants, three coffee shop interior images, and two musical stimuli. Essential to this study is the interpretive analysis of corresponding eye-tracking and interview data. The results show that visual perception is affected by auditory stimuli and other interior elements and factors associated with personal experiences; however, no distinct gaze pattern is identified by the type of auditory stimuli. The fixation patterns showed mixed reflections of the participants' perceptions, e.g., a single fixation pattern reflecting participants' likes and dislikes. Findings included six essential meanings of participants' gaze behaviors. This study suggested that auditory and visual stimuli are reciprocal in individuals' perceptions. Rather than one affects the other, the interaction between sensory stimuli contributes to the complexity and intensity of multisensory stimuli people associate with their experiences and conceptualize with meanings they establish.

Keywords: experimental phenomenology, eye-tracking (ET), interior design (ID), multisensory experience, spatial perception and cognition, visual attention (va), gaze behavior, commercial environment

INTRODUCTION AND BACKGROUND

Over the past two decades, neurodesign and neuromarketing have become growing disciplines of study. Design research has increasingly given attention to the complexity and multimodality of sensation, perception, and cognition. The scope of research on perception and the applications of results have been broadened and diversified in various fields such as cognitive neuroscience, computer science, design, marketing, and psychophysiology. The conceptual stances concerning what constitutes perception vary. In certain disciplines, including psychophysics and psychophysiology, perception has been conceived as subjective and representative of the mind, while physical stimuli are considered objective and representative of the body (Hoffman, 2013). Crucial to the interior design inquiries and practice is the phenomenological translation of the covert essence of one's action and perception into architectonic dimensions, not only to identify individual elements seen on the surface; human perception and cognition are often approached in conjunction with individuals' conceptions of places and their associations. Spatial experience consists of perceptions of tangible (or reified) elements of a setting and also the intangible, such as the "atmosphere" or "energy." Presently, various methods associated with emerging technologies [e.g., electroencephalography (EEG), eye-tracking, and virtual reality] play significant roles in design research concerning perception. The traditional design approach to understanding human perception has focused on the vision as the dominant human sense for acquiring information from the external environment. However, more recent design research presupposes that visual perception is part of spatial experience associated with emotions and feelings triggered by environmental attributes (Kwon, 2010, 2016; Lisińska-Kuśnierz and Krupa, 2020).

Due to the direct relationships among perceptions, emotions, and feelings, researchers have strived to measure complex human experiences in built environments properly. While emotions are immediate responses and reactions through biologically-based processes, feelings or moods persist as states span over more extended periods. Emotions and feelings play an important role in the behaviors and decision-making in built environments of individuals (Patel, 2005; Ibrahim, 2019); thus, these are critical factors to investigate in design research and how emotions and feelings are triggered. Emotions are how our brains respond to various stimuli and "tag" the information (e.g., positive or negative; relative intensity). Emotions are measurable; for example, they can be measured as to how "intense" or positive or negative—as shown in the circumplex model of affect (Posner et al., 2005), representing the psychological constructionist stance on measures of human emotions. In design research and consumer behavior studies, emotional responses have often been measured using self-reports (e.g., surveys and interviews), which can be useful when studies focus on whether some information (external stimuli) is memorable (Petermans et al., 2009; Umbas, 2015). Biometric measures of emotional responses have been increasingly implemented in interior design research, including using EEG to understand whether stimuli motivate the reactions of individuals and employing eye-tracking to study visual behaviors, such as what is noticed (Kalantari, 2019; Lisińska-Kuśnierz and Krupa, 2020).

Visual behaviors have been studied in cognitive neuroscience, computer science, consumer science, environmental design, and psychophysiology (Epelboim and Suppes, 2001; Andrá et al., 2015; Muldner and Burleston, 2015). Although eye-tracking is not a direct measure of visual acuity, it has been used as a useful tool in research and applications, such as usability research (Manhartsberger and Zellhofer, 2005), human factors research, and safety applications (Han et al., 2020), psychological/cognitive research (Mele and Federici, 2012), education and training (Tien et al., 2014), kinesiology and sports sciences (Lim et al., 2018), and car/airplane simulations (Palinko et al., 2010). However, a generally agreed limitation with eye-tracking data is that while these data can explain overt attention, i.e., what is observed and perceived, they do not contribute to understanding the covert, such as why and how. The limitation of eye-tracking and behavioral observation become significant shortcomings for design research, especially studies on occupant- or user-experience, e.g., post-occupancy evaluation. Due to these limitations, open-ended interviews and qualitative surveys have been used in design studies on human perception. However, the qualitative methods have often been criticized as lacking objectivity and limited in generalizability (Hegelund, 2005; Thorne, 2008; Charmaz, 2009; Cope, 2014; Vasileiou, 2018). Alternatively, studies justified qualitative and interpretive approaches for the richness of data, qualities of in-depth investigation, and the value of interpretive phenomenological analysis using a small sample (Braun and Clarke, 2006; Smith et al., 2009).

Our understanding of spatial perception and cognition remains limited due to the complexity of measuring, analyzing, and interpreting the phenomena. Auditory and visual stimuli always exist in ordinary interior settings, while the other sensory input can be more specific (to a certain degree) to their occupancy types, e.g., smell and taste foods at restaurants and touch clothes at garment stores. Individuals' attention to various visual information is requisite to their decision-making on purchasing in commercial environments. Although online shopping has become prevalent in the retail market of today, places like coffee shops inevitably involve physical settings to some degree—even for an online order pick-up—comprised of the human–human and human–environment contact and interaction in the multisensory environment. By implementing mixed methods that involved eye-tracking and qualitative interviews, this study explored an experimental phenomenological approach to investigate the relationship between individuals' gaze behaviors and the covert dimension of their audio-visual perceptions of commercial interior settings. This study uses coffee shop images as a convenient example of ordinary commercial interiors. Underpinning the multisensory concept of this study focused on the audio-visual is the phenomenology of perception of Merleau-Ponty (Merleau-Ponty and Landes, 2012): the senses are distinct yet indiscernible as united through the body in becoming its perception (2014). Based on the notion, this study presupposes that audio and visual perceptions are interwoven in a holistic multisensory experience.

The relationship and differences between philosophical phenomenology and experimental science have been discussed and interpreted such that science can explain what is observed and perceived, while phenomenology can provide information about why and how. Thus, qualitative-descriptive or phenomenological analysis and neurophysiological analysis are complementary, not contradictory (Vicario, 1993; Ihde, 2012; Albertazzi, 2019). One of the underlying assumptions of experimental phenomenology is that qualitative phenomena are irreducible to stimuli (Albertazzi, 2013). Experimental phenomenology includes empirical and theoretical approaches in juxtaposition. Although some might view the assertion as paradoxical, the logic in it is that researchers attempt not only to identify "what" they investigate (e.g., Minors and Harvey, 2015) but also uncover "how" and "why." Phenomenology is concerned with individuals' lived experiences and perceptions. Phenomenologists assert that human experiences are lived and subjective, the essences of which are not reducible to stimuli; moreover, they argue that neurophysiological data do not have the explanatory capacity (Albertazzi, 2013). Criticisms on phenomenology are that its methods and findings are unclear and limited and do not provide outcomes with pragmatic solutions for practicing professionals who often have more immediate goals than searching for the essential (Oliver, 2012, p. 410). From a phenomenological point of view, physiological and neuroscientific methods are too analytical to adequately explore the essences of human experiences, including visual perceptions (Vicario, 1993). As human perception is multifaceted, it may reveal unknown truth when approached from multiple points of view. Along with its experimental approach to gaze behaviors, this study implements phenomenological analysis, "a probing of what is genuinely discoverable and potentially there, but not often seen" (Ihde, 2012, p. 13).

Adopting an experimental phenomenological approach, this study investigates how auditory stimuli affect gaze behaviors and the hidden meanings behind the gaze patterns in audio-visual settings in commercial contexts. This study presupposes hidden meanings behind gaze behaviors, e.g., why individuals notice, pay attention to, and remember certain spatial attributes or elements; qualitative measures are requisite for uncovering the meanings that cannot be predicted through quantitative approaches.

The research questions of the study are:

1) What are the hidden meanings behind individuals' gaze behaviors in their audio-visual perception of interior settings?
2) Are gaze behaviors affected by the types of musical stimuli in coffee shops?
3) Do gaze behaviors represent visual preferences of interior settings?

This study implements mixed methods that involve lab-based eye-tracking and an open-ended interview. As the researchers did not find field-specific precedents involving qualitative and quantitative measures, this study gives greater attention to uncovering the essential meanings hidden behind gaze behaviors than testing hypotheses that may conflict with the phenomenological aspect integrated into this study.

EYE-TRACKING IN DESIGN AND RETAIL RESEARCH

Interior design aimed to provide human environments through the creative process balanced with a critical point of view on occupant needs and desires that are often subjective. Due to this two-fold approach, no single form of inquiry may sufficiently examine human experience in built environments. Instead, integrated approaches may better understand the complex nature of and interactions among the human senses and how a multisensory context affects one's perception of space. Spatial experiences involve complex and multimodal perception and cognition. Studies have found that the human brain can learn and process cue associations through multisensory experiences such as audio-visual and tactile-visual (Gori et al., 2012; Wismeijer et al., 2012). Cue associations are not innately present but established through individuals' subjective experiences that affect the perception of the individual and interpretations of the context. Minors and Harvey (2015) examined how the visual aspects of building interiors impact the acoustical experience of an audience in a concert hall. They pointed out that, when designing contemporary buildings, significantly less attention and time are allocated to finish details; instead, the focus is on building form. They suggested that gaining insight into what people look at may help designers understand what to focus their efforts on in design processes. Audio-visual experiences have been studied in consumer research. Mehta et al. (2012) examined how ambient noise in a cafeteria can affect creativity using a creativity test tool. They found that "a moderate level (70 dB) of ambient noise enhances performance on creative tasks and "increases the buying likelihood of innovative products" (p. 785). However, because ambient noise can vary, this finding may not be applied to all interior environments.

Eye-tracking has been used in design studies on spatial identification, navigation, and wayfinding (Viaene et al., 2016; Tang and Auffrey, 2018; Su et al., 2021). Eye-tracking is a useful method to measure immediate gaze responses to visual stimuli; the cognitive process, including the emotional or conscious motives or triggers for eye-fixations on specific objects of the individual, can be sought through phenomenological measures, including interviews. Eye-tracking research has its historical roots in cognitive research on reading (Just and Carpenter, 1976). In the early research and some recent studies on visual attention, the eye-mind hypothesis (Just and Carpenter, 1980) seemed to be adopted as a strong validation for the power of eye-tracking. The essence of the hypothesis is that people tend to pay attention to and think about what they are seeing. However, in some cases, the hypothesis might lead to overgeneralization or oversimplification, undermining the qualitative aspects of perception because mental processes are not always aligned with visual attention (Schindler and Lilienthal, 2019). Eye-tracking has been used in studies on visual behaviors of people in built environments, e.g., how individuals visually navigate space and orient themselves in environmental settings (Mazman and Altun, 2013; Viaene et al., 2016; Guntarik et al., 2018); how eye movement responds to other sensory input in wind parks (Yu

et al., 2017). Cognitive studies on esthetic judgments argued that gaze fixations are affected by the symmetry in architecture, visual arts, and faces; visual behavior represents an aesthetic preference for visual configuration and balance (Treder, 2010; Hodgson, 2011; Giannouli, 2013). Eye-tracking has also been implemented in retail studies: (1) the visual attention of customers to signage and products affects their purchasing probability at retail stores (Huddleston et al., 2015; Tang and Auffrey, 2018); (2) directional patterns (e.g., vertical and horizontal sightlines) in the visual navigation of consumers on retail displays (Atalay and Meloy, 2011; Goldberg and Helfman, 2011; Deng et al., 2016); (3) there is no significant or direct effect of the first fixation on consumer choice (van Der Laan et al., 2015); (4) consumers have a more favorable attitude and positive perception toward merchandise and service quality and feel more aroused or pleased in a store with social cues presented, e.g., in-store displays of graphics with a social implication (Hu and Jasper, 2006).

Interior design research has adopted eye-tracking, as gaze data can help reveal—to a certain degree—unspoken thoughts and biases that often occur in self-reports. However, the covert side of visual behaviors, the deeper meaning of the association between the thoughts and gaze behaviors of individuals, has not been discussed. Interior design practitioners and researchers put efforts into understanding the feelings, preferences, and interpretations of occupants of interior environments, not merely identifying material objects or features that might catch the eyes of the people. This study investigates whether and how auditory stimuli affect the gaze behaviors of individuals and the hidden meanings behind their visual attention to spatial attributes of commercial interior settings, particularly coffee shops.

METHODS

Eye-Tracking Metrics

Before detailing the research methods of this study, it seems necessary to overview the key terms and metrics of eye-tracking concerning a wider audience interested in adopting eye-tracking in research. The essential contents and metrics of eye-tracking data include gaze point, fixation, fixation duration, dwell time, and area of interest. These measures allow to verification of the visual patterns of individuals who have various levels of cognitive performance. A *gaze point* refers to the spot looked, which equals one raw data point captured by an eye tracker. For example, if the eye tracker measures 30 times a second (30 Hz), each gaze point represents a 13th of a second (or 33.33 ms). A cluster of gaze points in close proximity constitutes a *fixation* that is an effective measure of visual attention. *Fixation count* reveals how often a participant viewed the area of interest or refocused attention to that element (Huddleston et al., 2015, p. 568). The *time to first fixation* (TTFF) refers to the amount of time it takes an individual to look at a specific area of interest. The TTFF can indicate both bottom-up stimulus-driven searches (e.g., a neon sign catching immediate attention) and top-down attention-driven searches (e.g., individuals actively decide to search for specific elements or areas in a picture). *Areas of interest* (AOIs) are user-defined sub-regions of a displayed stimulus and are essential in analyzing eye movement and fixation data. The methods of AOI construction can vary and include hand-drawn (or selected) AOI, Voronoi tessellation, limited-radius Voronoi tessellation (LRVT), and grid methods. Types of AOIs include dynamic AOIs, gridded AOIs, planes, and whitespace. The type of AOIs is determined based on the subject of the study. Often in retail studies on consumers' visual attention to products and information on purchase intention, AOIs are created around products or price display signage in a specific display (Huddleston et al., 2018). *Dwell time* is the amount of time that a respondent spends looking at an AOI. Studies suggested that dwell time often indicates a motivational determinant and conscious attention. For example, longer dwell times, i.e., prolonged visual attention to a specific area, suggests a higher level of interest, while shorter dwell times indicate contents that might be more catchy (Farnsworth, 2018).

Heatmaps and scanpath plots (or gaze plots) are used to visualize gaze data. A *heatmap* displays the distributions of visual attention, which effectively reveals the focus of visual attention for a group of participants during the same time. In heatmaps, there is no information about the order of gaze points or focus on individual fixations. Heatmaps are color-coded, with red areas indicating higher fixation counts and suggesting a higher level of interest; yellow and green areas indicate lower fixation counts and lower levels of visual interest. Areas without coloring are likely to receive little or no attention. *Gaze plots* (or *scanpath plots*) show the location, order, and time spent looking at locations on the stimulus. The primary function of gaze plots is to reveal the sequence of where individuals look. Fixation duration refers to the time spent gazing and is shown by the diameter of the fixation circles in the data display (**Table 5** in 5.1.3), i.e., the longer the gazing time, the larger the circle.

Sample

The sample size for this study was determined based on the recommendations and guidelines found in precedent studies. Creswell (2013) suggested that 20 to 30 interviews be adequate for qualitative analysis; Morse (2000) suggested 30 as a working number for semi-structured interviews to reach theoretical saturation. Marshall (2013) analyzed 83 studies from information systems journals and recommended 15–30 for single case projects; Vasileiou (2018) analyzed 214 health research articles and found the medians of the sample sizes used in the studies published in three leading journals ranged from 15 to 31.

This study used a voluntary sample of 21 ($N = 21$) that consisted of 14 female ($n = 14$) and seven male ($n = 7$) university students in various majors, i.e., accounting, communication, computer science, design, fine arts, journalism, management, and mechanical engineering. For design students, the eligibility to participate in the study was restricted to pre-major first-year. The eligibility for all participants was restricted to US residents and English-first-language speakers. The ages of the participant ranged from 19 to 23 years old ($M = 20.9$; $SD = \pm 1.35$). Because the study was conducted without comparing data between gender groups, the researchers did not attempt to balance the participants in equivalent numbers. The eligibility for research participation was limited to individuals with no vision impairment: naked or corrected binocular eyesight +0.5

FIGURE 1 | Visual stimuli for eye-tracking experiments—photos of three coffee shops, from left, I-1, I-2, and I-3 (Kwon and Kim, 2018, p. 82; 2020, p. 447).

or higher; no color deficiency. For color deficiency tests, *Ishihara's test for color deficiency* (Ishihara, 2012) was used.

Equipment and Tools

The quantitative method used in this study was derived from a prior study on gaze fixations, saccades, and blinks in audio-visual perception (Kim and Kim, 2020). However, the study pointed out that its quantitative tool and method could neither the meaning of the gaze behaviors nor the "joint effect of multisensory cues" (p. 9). Regarding the critical limitations, this study aimed to explore the qualitative and interpretive facets of gaze behaviors in interior environments.

For unobtrusive head-free eye-tracking, a screen-mounted eye tracker, SMI REDn (with a sampling rate of 30 Hz), was integrated into a 27-in. 1,920 × 1,080 pixels widescreen monitor. SMI BeGaze 3.7 was used for analysis and visualization of raw gaze data. Normalizing light and controlling noise is crucial in eye-tracking because various environmental factors can cause blinks and lookaways and thus, affect the quality of eye-tracking measurement. Eye-tracking experiments were conducted in a lab setting that resembled a darkroom in a quiet location to isolate the experiment setting from sensory distractors.

The visual stimuli used were photo images of three franchised-brand coffee shops (**Figure 1**) located in Seoul, Korea, with no culture-specific design feature. Each image shows ∼8 × 6.5 m of the interior space of a coffee shop, including the order/pick-up and seating areas. The viewing distance for eye-tracking was set at 600–650 mm. The images naturally include coffee shop workers and customers *in situ*. Each image shows four people (including full and partial figures), including one customer interacting with a worker. The researchers did not modify the visual presentation of the interior configuration, as the real-world situations were better suited to the study than ideally controlled mock-ups that better fit studies testing hypotheses.

As auditory stimuli, two songs in different music genres, jazz-pop (M1) and dance-pop (M2) were used. These songs were chosen to simulate two common types of sound atmospheres in commercial settings. A field survey was conducted to identify the most played musical genres in eighty coffee shops. The musical pieces played in the coffee shops were categorized into six genres (i.e., new age, dance-pop, ballade, old pop, electronic, and jazz-pop). Of the six, jazz-pop and dance-pop showed the highest frequency scores (N = 109: jazz-pop = 37; dance-pop = 29; ballade = 23; old pop = 14; no music = 3; electronic = 2; new-age = 1). A jazz-pop song (M1) in 88 beats per minute (BMP) and a dance-pop (M2) in 137 BPM were selected and used as the auditory stimuli in data collection. The languages used in lyrics were not controlled: M1 in English and M2 in Korean.

An open-ended interview questionnaire was used: primary questions (10) and up to three probing questions for each of the primary. Probing questions were selectively asked, dependent upon the responses of each participant to the primary questions. Because an interview is a self-report by its nature and is often in a face-to-face setting, interview participants sometimes seek "correct answers" when responding to questions, which results in overly articulated or summarized responses. To minimize such a risk, an open-ended interview questionnaire was carefully designed based on the construct of the symbolic interactionism of Blumer (1969): the self (self-conception/identification), object (abstract, physical, or social), social interaction, and joint action. The symbolic interaction framework is suited to this study, as its holistic view concerns the meaning of human–human and human–environment interactions, which is essential to research on spatial experience. The sequence of interview questions was derived from prior studies adopting symbolic interaction approaches to research on meanings of interior environments (Kwon, 2010, 2016). The questionnaire also included questions about the experience of participants of the eye-tracking experiment setup and procedures at the end.

Data Collection

The eye-tracking data of each participant were collected through the following procedures:

1) Before showing images to each participant in eye-tracking, a short instruction was displayed on the monitor: "please look at the image on the screen as if you are looking around inside the coffee shop presented."
2) One photo image paired with a song was displayed on the screen (viewing distance 600–650 mm) for one 60-s period.
3) A 10-s break was given between two sessions while the monitor displayed a blank white screen.
4) Per participant, the procedures (2) and (3) were repeated six times in total, using I-1, I-2, and I-3 paired with M1 and M2 in random order: I-1/M1, I-1/M2, I-2/M1, I-2/M2, I-3/M1, and I-3/M2.

TABLE 1 | 12 × 12 gridded areas of interest (AOIs) of I-1, by music and time-segment (T1 exampled).

	Jazz Pop (M1)	Dance Pop (M2)
T1: 00-10 sec.		

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0.1	0	0	0	0	0	0	0
3	0	0	0.3	0.2	0	0.1	0	0.1	0.4	0	0.1	0
4	0	0.2	0.4	0.5	0.5	0.3	0.1	0.7	0.2	0	0.1	0.1
5	0	0.7	0.2	0.5	0.1	0.1	1.6	0.1	0.1	0.1	0.1	0.2
6	0.2	0.5	0.2	0.7	0.3	0.2	0.5	0.1	0.1	0.1	0.1	0.1
7	0	0.2	0.2	0.6	0.7	0.1	0	0.1	0.1	0	0	0.3
8	0	0	0.1	0	0.2	0	0	0.3	0.1	0.2	0.3	0.1
9	0	0	0	0.1	0.6	0.2	0	0.1	0.1	0.1	0.1	0.1
10	0	0	0.1	0.1	0.2	0	0.4	0.1	0	0.1	0	0
11	0	0	0	0	0.1	0	0.8	0.1	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0.1	0	0	0.1	0	0	0.1	0	0	0	0
2	0.1	0.1	0	0	0	0	0	0	0	0.1	0	0.1
3	0	0	0.2	0.2	0.1	0	0	0	0.4	0.1	0.1	0.1
4	0	0.3	0.4	0.3	0.6	0.1	0.4	0.9	0.2	0.1	0.1	0.1
5	0.1	0.7	0.1	0.4	0.1	0.2	1.7	0.3	0.1	0	0.1	0.1
6	0.2	0.8	0.2	0.8	0.7	0.2	0.5	0.1	0.2	0.1	0.1	0.2
7	0.1	0.1	0.2	0.3	0.5	0.3	0.2	0	0	0.1	0.1	0.1
8	0	0	0	0.2	0.1	0	0	0.2	0.1	0.1	0	0.4
9	0	0	0	0.1	0.3	0	0.1	0.2	0.1	0.2	0.1	0.2
10	0	0	0.1	0.1	0.2	0.1	0.3	0.1	0	0.1	0.1	0
11	0	0.1	0	0	0.1	0.2	0.3	0	0	0	0	0
12	0	0	0	0	0	0	0.1	0	0	0	0	0

A 30-min open-ended interview followed the eye-tracking experiment of each participant. Interviews were conducted in a separate meeting room adjacent to the eye-tracking lab, without sensory cues for retrospective recall. All interviews were conducted by the same interviewer who was not previously acquainted with the interviewees. The open-ended retrospective interviews focused on the feelings and thoughts of participants on the perceived spaces and sounds during their eye-tracking experiments. The participants were also asked a separate set of questions about their experience of the eye-tracking experiment set-up and procedures at the end of the interview.

Data Analysis and Interpretation

Data analysis consisted of four phases:

- Quantitative analysis and visualization of gaze data
- Content analysis of the visualized gaze data
- Content analysis of interview responses
- Comparison of the three sets of analyzed data.

A total of 3,600 (60 s × 2 music pieces × 30 Hz) fixation data per participant was collected and analyzed. Each 60-s session associated with one music piece was broken into six 10-s segments (from T1–T6). The 10-s unit was determined based on precedent studies (Kim and Jung, 2012; Kim and Kim, 2018) on time-sequences in spatial observation, which compared 3-, 5-, 10-, 15-, and 30-s segments and found 10-s most effective. The averages of fixation count and fixation duration with music 1 (M1) and with music 2 (M2) were compared. Scanpath analysis was conducted to identify similar patterns of fixations among participants. In this study, the 12 × 12 Gridded AOIs (**Table 1**) were used. In **Table 1**, the number shown in each AOI grid indicates the average of the fixation count in the AOI. Heatmaps were generated by time-segment (10 s per segment) to visualize the general distribution of gaze points and identify the primary AOIs as the participants engage in the images.

The interview analysis included both descriptive and interpretive phenomenological processes. All interview responses were transcribed for content analysis. Due to the highly descriptive and various wordings by the individual, the interview responses transcribed were categorized by thematic context responding to the construct of symbolic interaction: brand/commercial elements to *object*, interior factors/atmosphere (including sound) to *object*, personal memories/associations to *the self*, human interaction to *social interaction*, and cultural factors to *joint action*. The categorized responses were analyzed in-depth compared with corresponding gaze data; then, multiple themes were derived from each context category; the researchers synthesized and interpreted the themes and determined six essential themes. Although the symbolic interaction criteria were used to categorize interview responses in the initial phase of analysis, the researchers did not attempt to match the six essential themes found back with the criteria because each essential theme encompassed multiple criteria of symbolic interaction.

RESULTS

The fall-out rate was 4.7%: 20 (13 females and 7 males) of the total sample ($N = 21$) were considered valid and were analyzed. The results illustrated in this section include the participants' gaze patterns found through eye-tracking and the contents or determinants (the "why") of the visual behaviors, which were found through in-depth interviews. Some limitations related to the findings from data analysis are also discussed in this section.

Findings From Eye-Tracking

Overall, the collected gaze data revealed considerable visual attention to areas with a quantity and complexity of visual information, including signs, menu, and sales products. The general patterns of the participants' fixations and scanpaths differed depending on the type of auditory stimuli, i.e., the music played during the experiments. Besides the interior elements and objects, the participants tended to pay attention to the interactions of people they found in the images. The following are the details of the essential metrics measured in this study.

First Fixations

In this study, the first fixated objects/contents and the pattern among the individual participants' TTFFs were important.

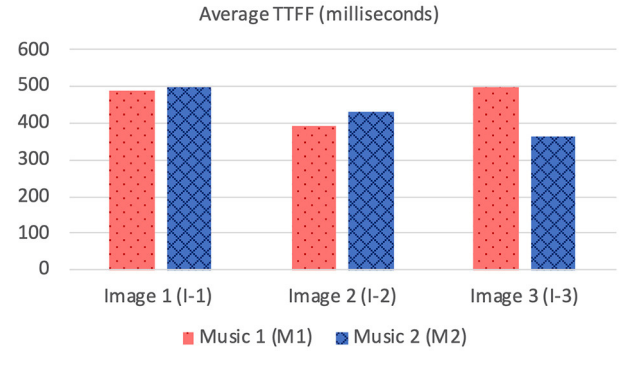


FIGURE 2 | Average time to first fixations.

Participants' first fixations were analyzed by time and contents: first fixations on each AOI were counted, and the contents in the first fixated AOIs were analyzed. The highest numbers of first fixations on the contents in I-1 and I-2 appeared in the order: (1) human figures, (2) corners or edges of interior elements or objects, and (3) signs, menus, or decorative text. The same order was found when I-1 was displayed, regardless of the music played. In I-2, many of the first fixations appeared on the two persons in interaction near the center of the image regardless of the music. When I-3 was displayed, the first fixations appeared in the order of (1) the large decorative text—"something to figure out"—on the wall, (2) corners and edges, and (3) human figures with M2 played, which appeared in the reversed order when M1 was played. With M1, 40% (n=8) of the first fixations (FF) were on two of the three human figures in the image (seven on one facing the viewer); the third FF (0.21 s) was on one facing the viewer. With M2, 70% ($n = 14$) appeared on the two persons in the image (50% on one facing the viewer and 20% on one showing its back).

Three images (I-1, I-2, and I-3) showed the same pattern: the average time to first fixation (TTFF) was longer when M1 was playing (**Figure 2**). Individual participants' TTFFs were varied. In I-1, 50% (n = 10) of the participants showed longer TTFF with M1 and 40% (n = 8) with M2. Two participants showed no difference in TTFF between the two auditory stimuli. The eighth of the 14 FFs took the shortest time (0.39 s), which was fixated on one facing the viewer. On I-2, 60% (n=12) participants showed a longer TTFF with M1, 35% (6) with M2, and two participants showed no difference between the two auditory stimuli. Seven of the 12 with M1 played were significant, and seven of the seven were significant when M2 was played. In I-3, 35% ($n = 7$) of participants showed longer TTFF with M1, 60% ($n = 12$) with M2. One participant showed no difference between the two auditory stimuli.

Although the type of each auditory stimulus by itself did not directly affect participants' first fixations or immediate visual attention, their interview responses (detailed in Section Findings from interviews: meanings of gaze behaviors) implied their engagement in analytical processes in the early phase of their visual experience with the faster music (M2). For example, the early fixations on corners of the interior structures and objects were related to the participants' attempts to visually define objects and interior configurations.

Gaze Fixations and Visual Attention

Regardless of the music played, the ranges of the average fixation count (**Table 2**) and the mean dwell time (**Table 3**) by time segment were greater with I-2 than I-1 and I-3. Overall, the average fixation count was higher in T1 (0–10 s) than T6 (50–60 s), and the mean dwell time was lower in T1 than T6. All fixation counts and durations were analyzed to compare the time to gaze "concentration," i.e., 300 ms and longer durations, and "high concentration," i.e., the longest 10% of the fixation data (**Table 4**). Regardless of the stimuli used, the average time to gaze concentration appeared between 11 and 15 s in T2 and high concentration between 32 and 39 s in T4. The results did not show specific patterns of differences in the types of music played. The faster or complex sounds affect individuals' grasp of surroundings and concentration on visual perceptions. However, the result should be further scrutinized as the time to gaze concentration and high gaze concentration was variable for individuals.

Gaze Plots and Heatmaps

When visualized, the gaze plots (**Table 5**) showed a more scattered pattern with M2, while higher fixation counts appeared in fewer AOIs with M1. Despite the differences in individual participants' scanpaths, general patterns were also found. With M1, there are more concentrated fixations, i.e., higher fixation counts and longer dwell time per AOI were found. With M2, more scattered fixations and shorter dwell times were found. This result reiterates the finding above, showing that fast or complex sounds may be a greater distractor and stressor, affecting individuals' grasp of surroundings and concentration on their visual perception. The findings from the open-ended interviews (see Section Eye-Tracking in Design and Retail Research) provide in-depth explanations of the various factors and attributes that trigger or affect such visual behaviors.

When no specific visual information (e.g., signs, menus, sales products, etc.) was provided, the architectonic configurations (wall corners, open ceilings, etc.) contributed to the participants' visual learning of the spatial order. In contrast to other studies using eye-tracking, it was unclear in this study whether the participants' visual attention tended to fall near the center of the images because of the visual symmetry. This result is also reflected in the heatmaps (**Table 6**), representing all participants considered valid ($n = 20$). Although a heatmap may show the general gaze pattern, the heatmap alone cannot provide sufficient content that designers often need, including the causes and influences on users' visual attention to specific areas or objects. Participants' interview responses detailed in the following Section (Findings from interviews: meanings of gaze behaviors) revealed more varied reasons for their gaze behaviors.

Findings From Interviews: Meanings of Gaze Behaviors

The open-ended interview responses revealed the participants' personal experiences, thoughts, and feelings associated with

TABLE 2 | Average fixation count by time segment.

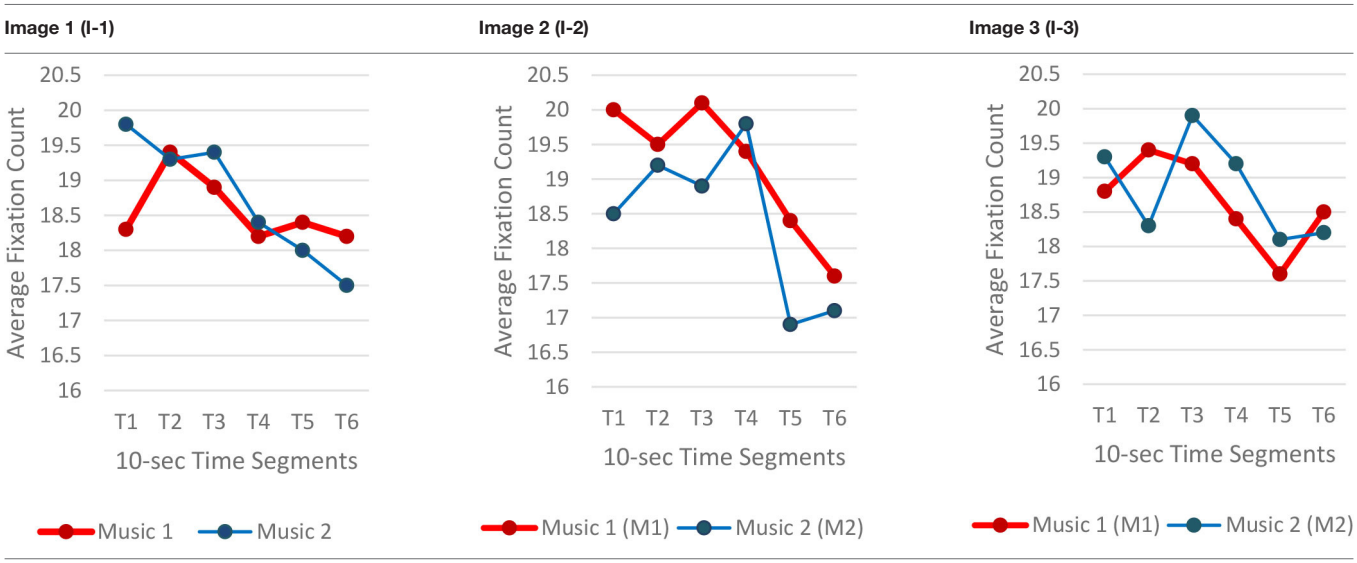
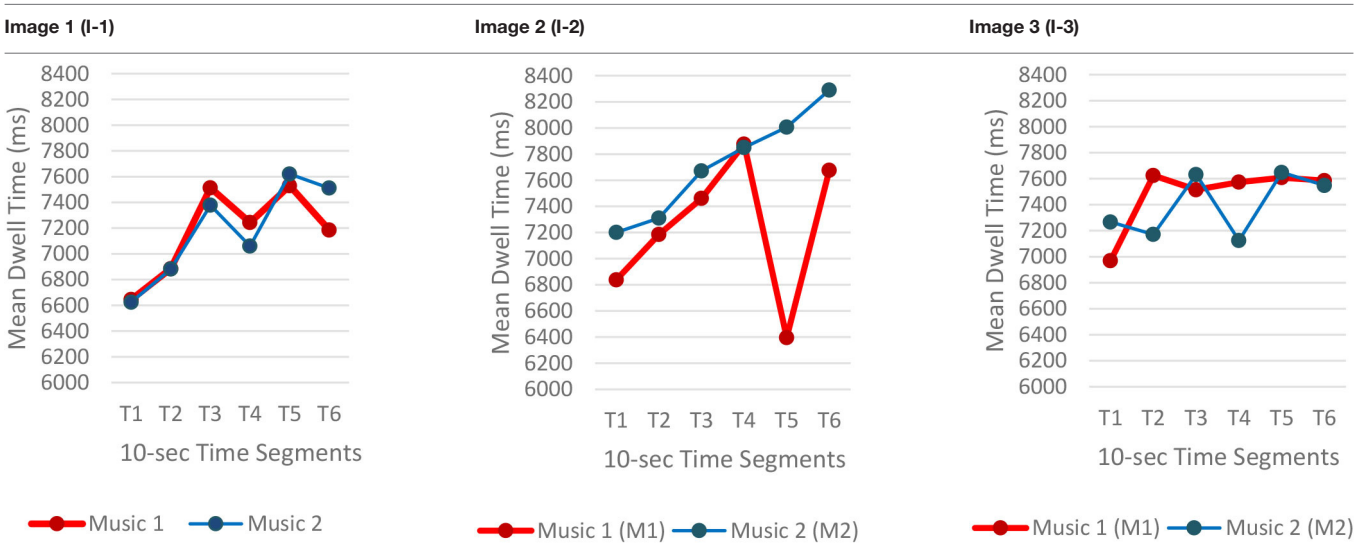


TABLE 3 | Mean dwell time by time segment.



their experience of the audio-visual stimuli, coffee shop interior images paired with musical pieces. Six essential meanings of their gaze behaviors were found through content analysis: (1) cross-sensory association and sensory overload, (2) attentional blindness, (3) the focal and ambient vision, (4) past experiences and meaning association, (5) attention to the unusual, and (6) human interaction and sociocultural association.

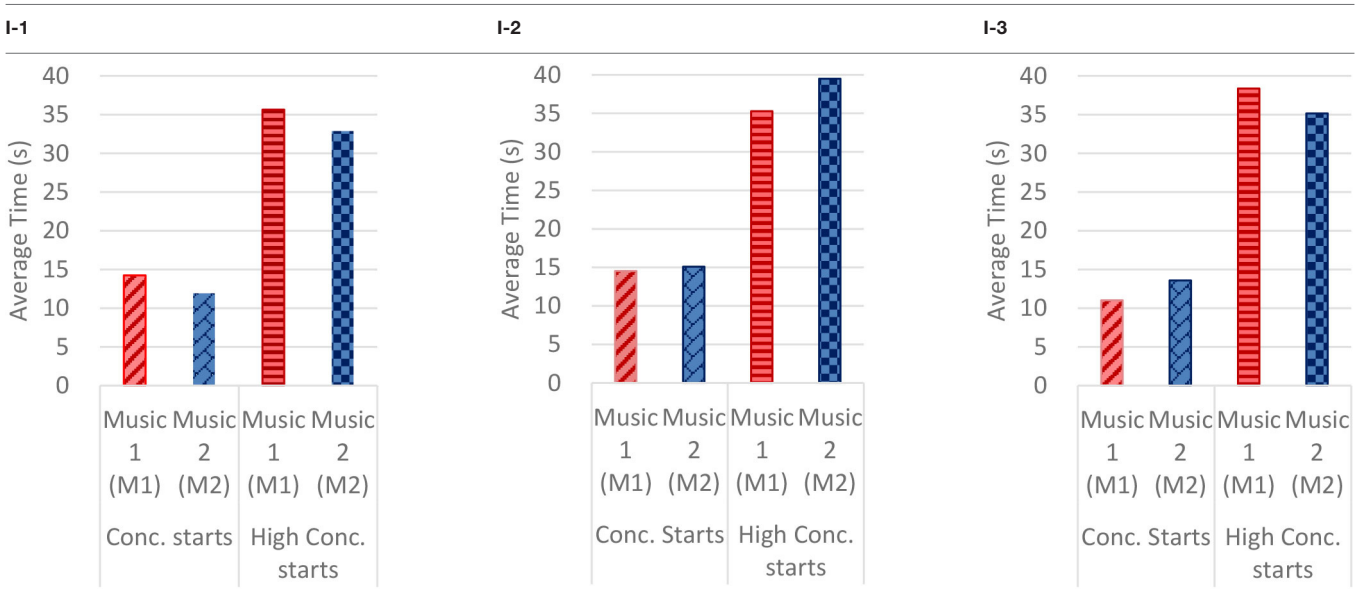
Cross-Sensory Association and Sensory Overload

While their wordings varied, most participants expressed cross-modal sensory associations to a certain degree, e.g., feeling (not seeing) visual crowdedness associated with the auditory stimuli and feeling (not hearing) noise in their visual perceptions. Participants also associated the brightness of the coffee shop images with noise or crowdedness. They felt the space in a photo they perceived brighter than the others busier and more crowded, despite the coffee shops in the three images were equally populated (**Figure 1**).

> The coffee shop [I-1] felt a little…noisy. I could feel some motion…the people…I could tell that they were moving. I could almost hear a blender going on and off. I could see it getting crowded fast. … I saw two employees. (Participant #10—P10)
>
> I felt like it [I-3] was quiet. And like I said, the grey color tones especially added to the quietness of the space. (Participant #03—P03)
>
> My eyes first went to the quote that was on the huge back-lit panel [I-3], which was like yelling out. (Participant #08—P08)

Other participants associated the photo images with a certain (imaginary) noise level, apart from the music played during the

TABLE 4 | Average time to concentration and high concentration.



experiment. The reasons for the responses were varied. Despite the controlled sensory settings that excluded or minimized gustatory, olfactory, and tactile stimuli, several participants expressed sensory overload experienced when the auditory and visual information was provided during experiments. A few participants specifically mentioned that M2 in fast beats was obstructive while there was much visual information to comprehend:

> When the faster music [M2] was playing, there was too much going on. I was trying to take in information and look around. Having extra stuff going on in the background, especially moving really fast and having a lot of musical parts to it, um…took away from the experience. It made it seem more crowded and less comfortable. (Participant #09—P09)
>
> I feel like I generally leaned towards the Norah Jones song [M1] in…all of the spaces. The other song played, I think it was like a K-pop song or something. I don't know. It's kind of stuck in my head now. Yeah, I liked it. It just was a little too much. (Participant #18—P18)

Table 5 in the previous Section (0.1.3) showed the gaze plots associated with Participant #09 (P09) quoted above. With M2 (dance-pop) played, the fixations appeared more scattered, showing a lower fixation count per AOI than those with M1 (jazz-pop). Despite the pattern of fixations, P09 and several others recalled the visual features better while expressing their discomfort from the sensory overload. When participants said, "the music fit well with the space" or "the place seemed comfortable," they tended to remember more of the overall ambiance than specific features. Four participants specifically mentioned their awareness of a conscious process in which they "noticed themselves" looking at things and feeling differently about the space when the music changed. The interview responses suggest that individuals' gaze- or fixation-patterns in eye-tracking do not always represent positive feedback or definition of the settings. Significantly short dwell-times and scattered fixations may reflect negative feedback rather than the positive in certain circumstances, e.g., perceiving space (vs. sales products) in commercial environments.

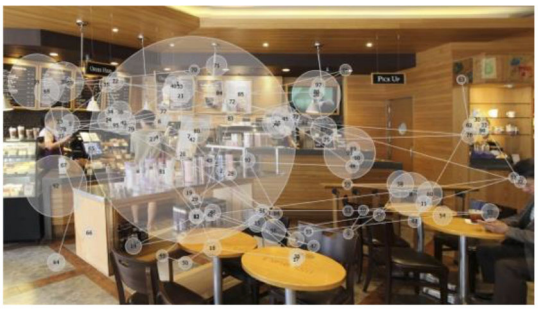
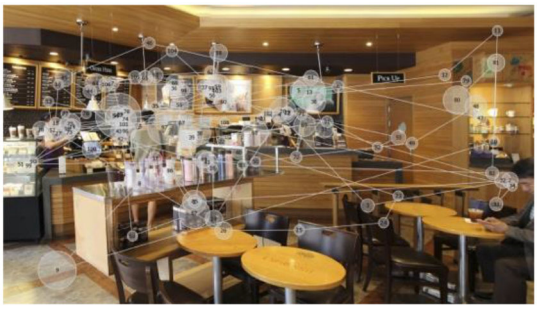
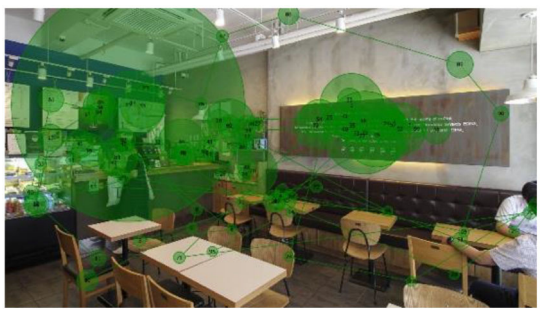
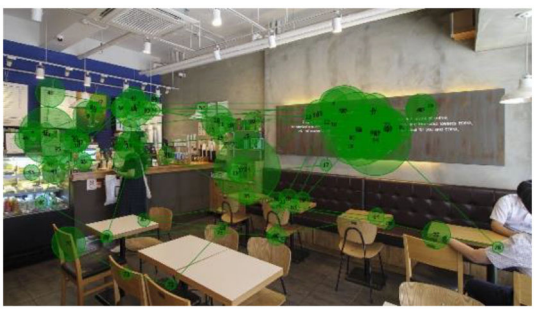
Uncertainty of task seemed to affect participants' feeling of sensory overload. With no specific task given to the participants other than looking at the images, they later expressed the minor stress felt during their eye-tracking experiments, i.e., the stress associated with "figuring out" where they were "supposed to look" while the background music was playing.

Attentional Blindness

Research has found that attentional blindness occurs during a high-pressure task, such as visual observation of an image when searching for a specific element or wayfinding in a spatial setting. Attentional blindness refers to "any failure to notice visual stimuli that can be attributed to attentional factors rather than perceptual impairment" (American Psychological Association, 2018). Although a high-pressure task becomes a stressor and results in attentional blindness in specific contexts, the current study found that attentional blindness can also occur in positive perceptual experiences. For example, P21 remembered many details of I-2, including the lighting fixtures and the ceiling color. However, the participant did not notice the exposed ceiling structure with a large suspended panel:

> I liked it [I-2] was inviting and comfortable. I liked the long counter with light and the three big pendant lights over the long wood table. I don't remember the ceiling. I think it was dark—remember it was black. It had to be. I don't think that there was a lower ceiling—that also might have been exposed, but I just didn't notice it. (Participant #21—P21)

TABLE 5 | Gaze plots by music (Participants #20, #09, and #05 exampled).

	M1	M2
I-1 (P20)		
I-2 (P09)		
I-3 (P05)		

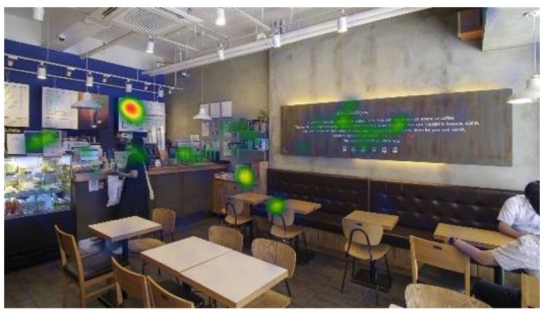
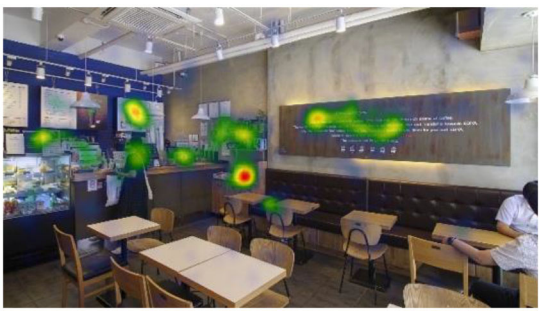
The Focal and Ambient Vision

Participants' interview responses revealed the association between their perceptions of objects and scenes and the focal and ambient vision. Studies have found that a built environment is experienced by two fundamental means: conscious focal processing and intellectual assessment and pre-conscious ambient spatial processing. While the central vision aids in processing focal awareness or conscious attention to objects, the peripheral vision aids in processing actions relating to objects and navigating motion through space (Rooney et al., 2017). In this study, the participants who mentioned the interior lighting of the coffee shop images associated it with the interior colors and materials first and then the overall atmospheres that are spatial contexts rather than objects or structural configurations on which one's gaze can focus. Thus, the participants' fixations and scanpaths could not provide evidence of meaningful attention to lighting even though they, including P12, specifically talked about their feelings associated with the interior lighting and color.

> It was very obnoxious. The lighting [in I-2] was just so yellow, like a sickly kind of yellow, not a warm yellow. Just like uh… Just nasty. In your face, yellow. (Participant #12—P12)

Participants also expressed a sense of spatial volume, which is ambient awareness, associated with the impression of "cheap" or "fancy," even though the three images used were of similar types of franchised brand stores with similar sizes. However, the participants' judgment did not always seem to reflect the participants' personal preferences.

TABLE 6 | Heatmaps: red areas indicate higher fixation counts and yellow and green areas show lower fixation counts.

	M1 (jazz pop)	M2 (dance-pop)
I-1 (T1-T6)		
I-2 (T1-T6)		
I-3 (T1-T6)		

> The first one [I-1], it seemed really tight. That one to me, it felt almost kind of cheap at first. I think that also had to do with relation of places I've been to in the past. It had like a similar feeling so—it also after I compared it to the other two. (Participant #10—P10)
>
> One [I-2] was the really big wooden one that had the bigger tables. It was the fanciest one. Uh, there were two women at the counter. Then the second one [I-3] was the smaller, cheaper one. I also liked the cheaper one was cozier. … I think it had like the white walls that just had the lights like these hanging down. And that one seemed like a lot more of a neighborhood coffee shop that I would go to. (Participant #12—P12)

The interview responses showed evidence of two different areas of visual perception. First, the central vision identifies an object and its visual properties (e.g., color, form, and material) perceived in high resolution. Second, peripheral vision relates to ambient awareness (e.g., detecting light, motion, and space). The results also suggest that the perception of light is one of the environmental factors that are less affected by attentional blindness than other visual objects or factors are. The interaction between light and color can be perceived regardless of particular gaze fixations, creating a general context, i.e., a kind of background. Due to the mechanism of the fovea, the degree of acuity in visual perception decreases depending on the distance from the visual attention point of the person, e.g., in the order of fine detail, gross detail, color, motion, and contrast and spatial volume.

Past Experiences and Meaning Association

Participants' perception of the audio-visual context used in this study appeared mainly as "preferred" or "fit in the context"; e.g., they "liked" or "disliked" the music, the music "went well with the

space," and the music "felt right in the space." Specific association between the sound and the visual reflected their judgment based on their past experiences; e.g., the music makes the coffee shops look "high-end" or "low-key," or the music fits a particular age group. While visual imagery directly influences what we see, recollections of past experiences may also shape perception itself (Pearson et al., 2008). Based on their personal experiences, the participants described the M1 as cliché, classic, nostalgic, moody, or natural and associated it with "high-end" interiors; alternatively, they described M2 as inviting, energy-boosting, vibrant, or upbeat, and associated it with "low-key" Interiors. However, such labeling did not provide a direct indication of personal preference.

> They were playing Norah Jones music. It was…friendly, relaxing. The music added a lot to the atmosphere. My Mom had that on CD… kind of nostalgic to me. (Participant #13—P13)
> Some of the stuff that I saw in the cheaper one looked like stuff I could get at IKEA. I kind of liked it. Now I feel bad to keep saying "cheap one." Um…it's homely, let's call it that. (Participant #12—P12)

As these results suggest, gaze movement and fixation may not be direct indicators of individuals' preferences for their surroundings. Thus, using the gaze data without corresponding data such as interviews or surveys could result in misinterpretation of visual behavior.

Attention to the "Unusual"

Participants seemed to have certain expectations, e.g., where to look to find necessary information for their tasks or spatial characteristics with which they were familiar. They pointed out certain features that they found unusual or unexpected.

> Maybe it was a TV, but that wouldn't make a lot of sense for it to be a TV. It was like a woman who had a clipboard or something, and it was like a green background. Um… I don't know, it was super weird. I just kept looking at it. (Participant #19—P19)

A few participants who had worked at coffee shops responded from the point of view of an employee by envisioning themselves as working in the coffee shops they viewed.

> That one [I-1] had like a lot of the extra stuff that I thought was unnecessary like they had the wooden bar fence coming up in the middle of the floor just to separate the people in line buying from the customers sitting down. So, I thought that was kind of useless and takes up space for no reason. I saw that and was like that just looks annoying. I used to have to sweep the floors and stuff, and you have to move tables and everything. So when I saw stuff that was heavy to move or stuff that was not moveable and was just in the middle of it I was just like uh. (Participant #10—P10)
> So, [in I-1,] I saw the door to what I assume was the dish room or the stocking and stuff. Was away from the bar. It wasn't behind the counter. It's usually away from customers, and behind the counter, so they can't go in there and mess around. But it was right in the hallway where you can pass and go to the bathroom. That got on my nerves because you have to keep going in and out, and I wouldn't want to have to carry all of that stuff. I actually worked at Starbucks for years. So, when I looked at, it was like I was walking in to go to work. (Participant #12—P12)

Others pointed out a few other features that they felt stood out. The gaze plots and heatmaps (**Tables 5**, **6**) shown in 4.1.3 also reflect their attention.

> I liked their little quote on the wall [I-3]. Their business had like– I don't know- they were talking to their customers or whatever. (Participant #03—P03)
> [I-3] My eye kept going back the blue background, painted brick, which I liked, and I felt like less corporate other than the sign with the quote. The menu…it seemed more handpicked where everything was than like I said, a template. (Participant #14—P14)

Human Interaction and Sociocultural Association

As mentioned previously, the gaze data showed a considerable pattern of fixations on human figures in the photo images, which were also reflected in the gaze plots (**Table 5**). Seven of 19 participants remembered the human interactions—either apparent or implied—they found in the images during their experiments.

> There were definitely more people there [I-3], but I think that actually helps with making it more inviting. Like seeing other people there for some reason makes me think, "oh, I want to be here too. (Participant #21—P21)
> I think there [I-3] were white tables, and then there were the two guys sitting in the corner. That felt like anyone could go into really—like you could just go with your friends. In the coffee shop [I-1] with the espresso table, there was like an older guy there, and he was on his phone. It just didn't really fit the scene, you know. (Participant #13—P13)

Individuals' sociocultural experience and understanding may play an important role in their spatial perception and interpretation. For example, several participants, including P03 and P13, associated particular visual elements with business aspects in their understanding.

> I liked their little quote on the wall [I-3]. Their business had like– I don't know- they were talking to their customers or whatever. Their business was like that. (Participant #03—P03)
> I know it [I-2] was really upscale because the lady that was ordering had like a Chanel bag—so I was like, "oh okay, its automatically upscale" because that's like thousands of dollars for the bag right there. So that kind of like changed my perspective. (Participant #13)

Individuals' familiarity or unfamiliarity with other types of sensory stimuli may also play an essential role in their visual perception and interpretation. Three participants associated M1 with high-class and M2 with low-key. They recognized the foreign language of the lyrics of the M2 and stated the coffee shop felt "cheap" because of the music. It was unclear whether the individuals' cultural or ethnic biases, rather than specific experiences, played a role in their responses.

> When it was playing the calm, classical music [M1], the café [I-1] looked more rich and more high class. When they were like playing Korean pop songs, um, playing Korean pop songs [M2] made the café look a little bit cheaper, but more geared towards the younger audience like college kids or high school kids. But um, when it was playing the other song [M1], the Norah Jones, it seemed more formal. (Participant #14—P14)

In this statement, the participant was referring to the same image, making the two opposing judgments associated with the two auditory stimuli. A few participants also noticed the lyrics in a "foreign" language and found it distracting because they attempted to determine which language it was. The result suggests that unfamiliar auditory input was "additional information" for the participants to comprehend, and thus, it became a stressor or distraction.

DISCUSSION

This experimental phenomenological study investigated the impact of auditory stimuli on individuals' gaze behaviors and the hidden meanings of their audio-visual perceptions of commercial interiors. The participants' gaze behaviors were affected by auditory stimuli and other interior elements and factors associated with personal experiences; however, no distinct gaze pattern was identified by the type of auditory stimuli. Six essential meanings of their gaze behaviors were found through interviews: (1) cross-sensory association and sensory overload, (2) attentional blindness, (3) the focal and ambient vision, (4) past experiences and meaning association, (5) attention to the unusual, and (6) human interaction and sociocultural association.

While participants' gaze data revealed the visual elements at which the participants looked, the elements were not always remembered. This study also found that first gaze fixation, fixation count, and dwell time indicate or imply visual interests and distractors or stressors. These findings can explain the reason behind the finding by van Der Laan et al. (2015) that there is no significant or direct effect of the first fixation on consumer choice. Participants noticed the details of various interior elements such as finishes and materials, fixtures and furniture, and colors and lighting, as much as the spatial configurations. They remembered those factors as interior atmospheres or general styles rather than individual elements that constituted specific objects or architectonic space. They related the interplay among those factors, especially between color and light, to their feelings, preferences, and sensory associations. It suggests that visual attention to certain interior factors such as color, light, materials, and finishes cannot be adequately explained or measured by eye-tracking as a stand-alone; thus, designers must consider sound- or noise-reflection and absorption in planning interior materials and finishes, concerning the impact of auditory conditions on occupant perception of visual information.

Although studies argued that visual symmetry and directional configurations affect gaze fixations and sightlines (Treder, 2010; Atalay and Meloy, 2011; Goldberg and Helfman, 2011; Hodgson, 2011; Giannouli, 2013; Deng et al., 2016), this study showed no evidence of greater attention to visual symmetry nor directional patterns (e.g., horizontal vs. vertical sightlines) in the scanpaths and heatmaps of the gaze data. Such gaze patterns may occur in certain types of retail stores with many sales products, displays, and other related visual information but may be less relevant to other interior environments that involve many human actions and interactions in consumers' sight.

A considerable number of participants' first fixations appeared on human figures in the coffee shop images, and these revealed participants' interpretation of perceived human interactions. This result supports studies that proved the impact of the social relevance of sensory cues on visual attention and perception of space: customers have positive perception and feel more aroused or pleased in a store with social cues (Hu and Jasper, 2006); visual attention and spatial orienting are interpersonally attuned to the *social relevance* of the cues (Gobel et al., 2018). Thus, interior configurations and features that can promote human interaction can help create positive visual rhetoric contributing to the place identity and enrich customer experiences in commercial environments.

The impact of the sound properties of the musical stimuli on fixation count and time to the first fixation appeared dependent upon the individual participants' experiences. Instead, it appeared that the total amount of sensory stimuli as a whole had a greater impact on their visual experience and comfort levels. Any unfamiliar stimuli may affect one's sensory experience and become stressors or distractors. Several participants felt the Korean lyrics of one of the auditory stimuli distracting while looking at the coffee shop images; a few participants even mentioned it made the space look cheap. This suggests that when research tools or materials include culturally oriented components, it is important for the researchers to be aware that unfamiliar cultural factors can trigger one's discomfort or bias in spatial perception and its interpretation and judgment of the design. It is an important implication for interior architecture and design in which there has long been criticism that, despite the industry being globalized, the profession lacks diversity and related data (Nieminen, 2020).

Participants' gaze behaviors and visual preferences did not always correspond. Depending on the individual, great visual attention may represent either positive or negative interests or preferences. Interviews revealed the close relationship between the participants' personal preferences of the visual settings and their past experiences, many of which involved interaction with or judgment against other people. Thus, research methods to investigate visual attention and preference need researchers' further attention to avoid confusion or misinterpretation of the relationship.

There were limitations in this study. Individuals' gazes respond to three-dimensional spatial settings differently from two-dimensional still images. Using photo images lacking depth or distance projection might have affected participants' visual experience due to the limited range of perceptual and spatial variations in the on-the-screen spaces. In the same vein, the lab setting, including a screen-mounted eye tracker, could not sufficiently resemble a real-life space that involves various sensory factors, movement, and human interactions in its lived

context. However, the lab-based eye-tracking experiments have meaningful implications for future studies involving various virtual environments that have increasingly become part of our everyday life. Several factors in this study might have added unintended distractions to the multisensory context, including the auditory stimuli with the lyrics in two different languages (English and Korean). The participants, English-first-language speakers, felt Korean, a foreign language to them, was distracting, perhaps because it involved another dimension of perception.

When asked during interviews, participants expressed that the silent 10-s break time between 60-s segments felt long and awkward because they were sitting in a dark room staring at a blank white screen. Although the speaker volume was set consistent during experiments, several participants reported they felt one auditory stimulus louder than the other, which informed that the sound decibels also need to be controlled to minimize confounding factors. Another factor to consider differently in future research design is the auditory stimuli repeated three times during each experiment, as the participant learned the pattern, possibly feeling sensory fatigue or losing interest.

CONCLUSION

Adopting an experimental phenomenological approach, this study investigated the relationship between gaze behaviors, audio-visual stimuli in commercial interior environments, and the hidden meanings of the gaze behaviors. The findings suggest that auditory and visual stimuli are reciprocal in individuals' perceptions. Rather than one affects the other, the interaction between sensory stimuli contributes to the complexity and intensity of multisensory stimuli people associate with their experiences and conceptualize with meanings they establish. Although limitations were found, whether expected, most meaningful was the methodological exploration in this study that informed better about the environmental attributes affecting spatial perception and why they affect. Based on the thematic meanings found through this exploratory study, future studies may be designed with more controlled variables to scrutinize the specifics and their statistical significance.

Eye-tracking research in design disciplines has often focused on measuring gaze responses to identify visual elements that catch people's eyes. However, interior design researchers need to understand that eye-tracking is useful in measuring eye movement within the focal vision and gaze fixations on objects, but not for the spatial perception that involves certain attributes to which the peripheral vision responds, such as light, color ambiance, and spatial volume. This study shows that eye-tracking is not sufficient as a stand-alone method for interior design research on occupant visual behavior, especially for individuals' thoughts and feelings associated with their visual responses. Unless adopted for specific purposes, the traditional eye-tracking methods using two-dimensional images and screen-mounted eye trackers have unavoidable limitations in interior design research. Options for research on spatial perception can vary, e.g., screen-mounted vs.wearable eye tracker, still images vs.motion pictures, and multisensory stimuli vs.visual stimuli only. Varying viewing differences can also be considered, as increasing viewing distances can increase performance differences across eye-tracking devices (MacInnes et al., 2018). Because no one tool or material is always better than the others, determining an optimal combination of tools and materials can be the key to successful research.

Commercial interior environments continuously evolve as people engage in the ever-changing context. Designers desire to rigorously communicate with clients and occupants/users to learn from them, how they perceive their surroundings, and associate the settings with themselves. Design practitioners must understand that arbitrary assumptions or generalizations of certain interior elements' causal effects may be reliable. Since the hidden dimension of visual attention, perception, and preference has seldom been investigated, we hope that this study is the enterprise that opens a discussion that can contribute to the discovery of the deeper meaning of multifaceted occupant experience.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the datasets are not to be released unless permitted by the funding and sponsoring institutions. Requests to access the datasets should be directed to Jain Kwon, jain.kwon@colostate.edu; Ju Yeon Kim, kjy@ssu.ac.kr.

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

JK and JYK co-developed the study and conducted data collection and analysis. JK interpreted the data and wrote the paper. The authors provided final approval of the version submitted for review and publication.

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