NEUROMANAGEMENT AND NEUROMARKETING

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PUBLISHED IN: Frontiers in Psychology and Frontiers in Communication

frontiers Research Topics

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ISSN 1664-8714
ISBN 978-2-88974-806-8
DOI 10.3389/978-2-88974-806-8

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NEUROMANAGEMENT AND NEUROMARKETING

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Citation: Russo, V., Ma, Q., Clement, J., Jin, J., Liu, T., Zito, M., eds. (2022). Neuromanagement and Neuromarketing. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88974-806-8

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frontiers in Psychology

EDITORIAL
published: 08 March 2022
doi: 10.3389/fpsyg.2022.864566

Editorial: Neuromanagement and Neuromarketing

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Keywords: neuromanagement, neuromarketing, neuromarketing tools, neuro-physiological, consumers' decisions, organizational psychology

Editorial on the Research Topic

Neuromanagement and Neuromarketing

This editorial summarizes the contributions to the Frontiers Research Topic on "Neuromanagement and Neuromarketing" with the aim to disseminate knowledge to advance research in these fields, and to explore the connections with the main theories and research approaches in the field of Organizational Psychology.

According to recent studies on consumers' behaviors and decision processes, measurements based on the registration of neuro-physiological parameters result in objective data, neuroscience applied to marketing can reveal what is happening in the brain in response to stimuli from advertising increasing our understanding of the neural mechanisms involved in buying decisions and emotional processes. The neuroscientific and marketing techniques are recognized to be able to analyze the real and unconscious effect of marketing stimuli. Liu et al. demonstrated the positive impact of reviewers' disclosure of personal review record on consumers' purchase decisions. The study is very interesting in the current era of electronic commerce. The reviewers' self-disclosure seems to have a positive impact on consumers' perception of source credibility, which in turn shapes consumer willingness to accept certain messages as well as their willingness to buy. The authors used the event-related potentials (ERPs) technique into marketing related research about the effect of reviewers' self-disclosure of personal review record on consumers' purchase decision making, analyzing the impact of source credibility of OCRs (online consumer reviews) on consumers' decisions. This research represents one of the first studies highlighting the role of personal review record in consumer behavior. Finally, the authors used neuromarketing tools, combining behavioral and ERPs approaches, to understand how self-disclosure of personal review record influences consumer information processing and decision-making.

Michela Balconi et al. evaluated the presence of distinct cortical brain oscillations in consumers' brain while navigating in a store and the effects of the specific role of touch on the customer experience. The lack of studies investigating the psychological dimensions and emotional aspects involved in sensory consumers' experience in-store, considering the effect of the touch, by employing a neuroscientific approach makes this work of great interest. This study suggested the possible usefulness of the Beta band on the right frontal hemisphere, analyzing with an EEG to measure affective states and higher-order cognitive sensory aspects more directly in a wide range of areas of interest where touch is involved. The presence of beta band suggests a cognitive state of sustained attention and enhanced network activity of higher-order somatosensory areas encoding perhaps the sensory aspects of the stimuli.

OPEN ACCESS

Edited and reviewed by:
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *28 January 2022*
Accepted: *11 February 2022*
Published: *08 March 2022*

Citation:
Russo V, Ma Q, Clement J, Jin J, Liu T and Zito M (2022) Editorial: Neuromanagement and Neuromarketing. Front. Psychol. 13:864566. doi: 10.3389/fpsyg.2022.864566

Duan et al. used a Functional near-infrared spectroscopy (fNIRS) to explore the neural correlates of consumers' purchase decision on different cross-culture marketing strategies. This methodology is a very promising brain imaging modality for neuromarketing research. The authors used this non-invasive technology by monitoring the regional cerebral hemoglobin concentration changes to analyze the different brain activation in males and females in relation to the cross-culture marketing strategies of the transnational brands. They simulated a virtual purchase scenario and measured the behavioral and neural responses toward two types of advertisements of different cross-culture marketing strategy. Findings suggest cognitive and emotional differences between men and women in purchase decision making toward different cross-culture marketing strategy: women showed higher purchase rate when watching the original culture advertisements than the mixed culture advertisements; man did not show significant preference between these two types. Neuromarketing approaches allow researchers to better understand complex purchase decision phenomena and make more comprehensive the assessment of marketing strategies, by analyzing the underlying neurobiology which are neglected or unavailable in traditional behavioral studies.

To understand responses to stimuli that are seen often, such as daily commodities, we need research tools able to detect the non-conscious reactions that are impossible for people to put words on. Utilizing the neuromarketing toolbox with a variety of neuro- and bio-metric techniques has shown how this approach to research brings new insights to people's reaction to daily stimuli. Yuan et al. utilized EEG to outline the impact from the color on warning signs that we see daily, to clarify the non-conscious effect of the color. Previous research on this issue based on verbal or behavioral responses but were not able to explain how the people and especially their brain responded spontaneously to warning signs in different colors. The non-conscious responses to different designs that we see in our daily life is central to research within consumer neuroscience. Alvino et al. proved benefits in an EEG based research design, to find the correlation between different designs and individual preferences. Predicting how designs of wine labels impacted early preferences of what the consumers were exposed to, would not have been possible by any traditional research tools in our marketing research toolbox. Recent research with neuromarketing show how specific design or changes in designs can change decisions. Russo et al. (A) and Russo et al. (B) emphasize the value of knowing more about how and what consumers look at local fish product and how the label design can influence purchase. Findings from this research would also be relevant for other food industry categories knowing how to design labels and others information given on packaging. From other research (Clement et al., 2017) we know that certain product characteristics and intrinsic values that are essential for band perception and brand equity do not get the attention needed.

As for the issue of tools and methodology, neuromarketing techniques show the potential to promote our understanding of consumer behavior. Mandolfo and Lamberti compared four research methods investigating impulsive buying, including quantitative self-reports, laboratory investigations, fieldwork observations, and qualitative interviews. They demonstrated that self-reports and interviews are effective to assess the cognitive facet of impulse purchasing, while laboratory investigations and fieldwork observations are appropriate to examine the conative and visceral facets of impulsive buying. Even though, however, the authors further identified two limitations in traditional approaches, concerning over-reliance on self-reports and lack of real-time assessment of cognitive and affective processes during impulsive buying, asking for complementary methods such as psychophysiological and neuroimaging tools. In this vein, Mauri et al. verified effectiveness of the psychophysiological techniques of implicit association test and emotional facial expressions for the assessment of user experience while navigating website, emphasizing importance of the emotional impact raised by website. Focusing on neuroscience approaches, Pei and Li reviewed literature using EEG-based affective computing technique in marketing and pointed out a promising avenue for investigation of affective states of consumers. In addition, the authors also called for attention to interactions among multiple customers. In line with this idea, Leeuwis et al. examined moment-to-moment neural similarity across subjects using EEG when they listen to music and validated that neural synchrony carries high predictive value for popularity of music. Yu et al. further demonstrated that in live streaming shopping context a broadcaster with strong passion and preparedness could enhance neural synchrony across consumers. Taken together, these articles have shown that neuromarketing techniques are valuable complements to traditional research methods in marketing by providing additional, often less subjective, and in-the-moment information about consumption decisions and interactive experiences.

Finally, neuroscience tools were applied also in organizational studies. The issue of neuromanagement considered new perspectives for the work context and dynamics.

Balconi and Fronda offer an important support describing the hyperscanning paradigm, consisting in the simultaneous recording of the cerebral activity of two or more subjects involved in social and interpersonal tasks, useful to deepen human interactions, and employed to understand exchanges in the managerial context and interactions between leaders and employees. This allowed to investigate the neural mechanisms of synthonization associated to leadership style, exploring interpersonal brain mechanisms generated by social interactions.

Leadership and interactions with followers, has been detected considering consciousness by Psychogios and Dimitriadis, in the framework of the social brain theory, underlying the mutual dependent relations, and adding the concept of *Homo Relationalis*, suggesting that leaders are social brain constructed phenomenon, requiring an understanding of the human brain as a social organ. Authors indicates different cognitive styles to understand the balance of leader/follower in a person, influencing relations and decisions.

The study by Johannesen and Zak, considered trust and company's purpose which enhance job tenure, job and life satisfaction, productivity, and decrease stress. To understand trust in organization, the authors considered studies suggesting that the neurochemical oxytocin is released in the brain

after positive interactions. Through the measurement of employees' neurophysiology, motivation, and productivity, they identified eight behaviors though which organizations can affect trust. To quantify organizational trust the eight factors were operationalized in an OXYTOCIN measure, showing how trust and purpose can be key factors for productivity, satisfaction, health and reduced turnover, competitive points for organizations.

Finally, the study by Zito et al. focused on job assessment and neuroscientific measurement of candidates' experience during a job interview. EEG and skin conductance measurement allowed to identify the most engaging and stressful phases during a job interview. Moreover, this study allowed to identify differences in the interviewers' styles, showing that a quiet style produces less stress, allowing the candidate to conduce a performant interview, and allowing the interviewer to capture the candidates' potential. This study suggests implication for the assessment process and contribute to the neuromanagement understanding in the light of organizational psychology.

AUTHOR CONTRIBUTIONS

All authors contributed to the preparation and revision of the Editorial. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We thank all authors who participated in this Research Topic: their research and knowledge are important contributions for the advancement of this discipline.

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frontiers in Psychology

OPINION
published: 30 October 2020
doi: 10.3389/fpsyg.2020.598332

The Dialogue Between Two or More Brains: The "Hyperscanning" for Organization

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Keywords: hyperscanning, leadership, communication, neuroscience, neuromanagement

OPEN ACCESS

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *24 August 2020*
Accepted: *12 October 2020*
Published: *30 October 2020*

Citation:
Balconi M and Fronda G (2020) The Dialogue Between Two or More Brains: The "Hyperscanning" for Organization. Front. Psychol. 11:598332. doi: 10.3389/fpsyg.2020.598332

WHAT AND WHY "HYPERSCANNING"

When we engage in social exchange, we join information with one another by producing actions and simultaneously adapting to the other person's actions via a sharing of mental representation and action within- and between-individuals (Hari and Kujala, 2009; Konvalinka et al., 2014; Balconi and Vanutelli, 2016; Balconi and Fronda, 2020). It has been shown that this form of adaptation between partners is applied in the case of a common aim and perspective (Masumoto and Inui, 2013; Sacheli et al., 2013; Konvalinka et al., 2014). However, the neural mechanisms underlying this intersubjective coordination of perception and actions remain largely unexplored.

Research in social neuroscience and social science has only recently substituted the study of individual focus and singular brain in isolation, that react to "social" situations, with studies of inter-subjective and dual brains (Sebanz et al., 2006; Konvalinka et al., 2014). This change was suggested by the idea that social minds and brains reactions are intrinsically different when people engage in interaction, rather than act as single individual (Schilbach et al., 2013; Konvalinka et al., 2014).

In this perspective, hyperscanning paradigm can help to support and study this new perspective in neuroscience. It consists in the simultaneous recording of the cerebral activity of two or more subjects involved in social and interpersonal tasks (Balconi and Vanutelli, 2016, 2017b). Therefore, hyperscanning allows exploring interpersonal brain-to-brain responsiveness induced by social interactions. Indeed, previous studies showed that the reciprocal adaptation of two brains in interactions results in a consistent synchrony, as shown by some specific tasks (such as cooperative or competitive tasks) as an example of possible applications of such paradigm.

Indeed, since these tuning mechanisms cannot be measured in isolation (Vanutelli et al., 2015; Balconi and Vanutelli, 2017b), hyperscanning is useful for their investigation in different common interaction contexts, such as communication exchanges or joint-actions.

Specifically, the hyperscanning technique has allowed to abandon the classical experimental paradigms, which focused on the recording of individuals' responses in different social situations (Camerer, 2003). The study of the "social brain," indeed, is one of the emerging fields in neurosciences that has led, in recent years, to the investigation of the neurophysiological bases of the social behavior of two interacting individuals.

Hyperscanning, indeed, through the use of different neuroscientific tools, such as fNIRS, EEG, functional magnetic resonance imaging (fMRI) and biofeedback, allowed to detect the neural correlates of two or more individuals involved in various social interaction processes (Balconi and Vanutelli, 2016; Balconi et al., 2019a, 2020).

During different social interactions, mechanisms of imitation and joint attention occur between individuals leading to a greater attunement (Frischen et al., 2007). The first application of hyperscanning was concerned with the simultaneously measurement of two individuals' brain activity in different social situations related to the performance of an interactive task (Montague et al., 2002) or during economic exchanges (King-Casas et al., 2005). Other hyperscanning studies have observed the mechanisms of individuals' brain tuning during the performance of real interaction situations, as demonstrated by the study of Lindenberger et al. (2009), who have observed the neural synchronization of some pairs of guitarists.

Similarly, other studies have investigated the mechanisms of neural and peripheral synchronization during the performance of cooperation and competition tasks, the implementation of prosocial behaviors, and during communicative interactions (Balconi and Vanutelli, 2017a; Balconi et al., 2019a, 2020). Specifically, different mechanisms of brain synchronization or de-synchronization were observed during a cooperative situation in which inter-agent individuals had to synchronize their responses during the performance of an attentional task, compare to the competitive condition in which they had to try to answer faster than the partner (Balconi and Vanutelli, 2018). The mechanisms of brain tuning were also observed during a prosocial condition, in which two inter-agent individuals were asked to perform an attentional task before and after a gift exchange (Balconi et al., 2019a). Finally, brain and peripheral synchronization mechanisms were observed during a non-verbal communicative interaction characterized by the use of different gestures aimed at transmitting information affectively, socially, or informatively characterized (Balconi et al., 2020).

In the light of this evidence, hyperscanning, therefore, proves to be an excellent technique for investigating inter-cerebral synchrony mechanisms and communicative and relational coordination (Dumas et al., 2010).

THE APPLICATION OF HYPERSCANNING TO LEADERSHIP STYLE AND COMMUNICATION

Considering the different leadership styles, such as the transformative and the authoritative one, some recent studies have used the hyperscanning paradigm to investigate fundamental phenomena within the managerial context, such as the moment of employees' evaluation (Balconi et al., 2019b). Indeed, the hyperscanning has shown itself as the more adaptive technique to observe the mechanisms involved in the communicative exchanges between leader and employee. Indeed, the competence to synthonize with the other one involved in the interaction appears to be fundamental for the formation of profitable and productive working relationships (Balconi et al., 2011; Balconi and Canavesio, 2013).

Starting from current literature, which observes how empathy and others' understanding lead over time to brain and body tuning mechanisms, recent research has been interested in investigating the neuro and physiological correlates associated with these tuning mechanisms. Our study also, through the concurrent use of EEG and biofeedback, aimed to recognize the lexical and neurophysiological markers related to the interactions between leader and employees by investigating the neural mechanisms of synthonization associated to the style of leadership, the role played within the organization, and the significant topics revealed by the employee evaluation interview. These points are fascinating because the ability to better interact with others provides some positive outcomes, increasing the sense of self-satisfaction, resilience, and physical and mental well-being, reducing stress levels (Balconi et al., 2019b).

In light of this evidence, the consideration and the analysis of interpersonal, communicative, and emotional processes underlying organizational contexts is essential.

In particular, one of the most examined topic concerns the role of leader and its interpersonal effects on the organizational context. Indeed, efficient relationships between managers and employees can directly cause effects within the organizations (Balconi et al., 2019b). In a recent study, Jiang et al. (2015) have investigated the role of interpersonal neural synchronization (INS) mechanisms in the emergence of leadership, observing if the latter are correlated with communications' quality and frequency.

In particular, to this aim, the cerebral activity of three groups composed of 11 members was recorded with the use of fNIRS in hyperscanning during a leaderless group discussion (LGD) task. The discussion of the groups of participants was video recorded and coded to investigate leadership and communication (Jiang et al., 2015).

From results, a greater level of INS emerged in the left temporo-parietal junction (TPJ), more implicated in processes of social mentalization, within the dyads composed of leader-follower (LF) compared to follower-follower (FF) ones. Specifically, a significant difference has emerged regarding the frequency of communication, which is higher for LF dyads than FF ones. On the contrary, no differences have emerged concerning the frequency of leader initiated and follower-initiated communication (Jiang et al., 2015).

These authors observe that as evidenced by evolutionary theories, which report human and non-human animals' tendency to develop skills useful to compete for survival, human leaders play a fundamental role in maintaining group cohesion (Jiang et al., 2015). Indeed, leaders have to consider their own needs

and that of their followers to facilitate the cooperation between the group members.

As interesting demonstrated by different neuroimaging studies, during cooperative situations compared to competitive ones, individuals' neural activity appear to be more synchronized (Cui et al., 2012; Jiang et al., 2015).

Furthermore, the INS is connected to the level of interagents' understanding (Stephens et al., 2010; Jiang et al., 2015), but it is not yet clear whether it is involved in the leader's emergency.

Moreover, it has been shown that high-quality communication increases the level of mentalization of individuals, consisting of the ability to understand social situations by adapting their behavior to others. Verbal and non-verbal communication skills, indeed, have been considered as a fundamental competence of the leader (Jiang et al., 2015). In fact, it is assumed that leaders' emergence occurs in conjunction with the development of good communication skills, relating to knowing how to use the right words at the right time. Through the use of EEG in hyperscanning, an increase in delta activity was observed in leaders assigned a priori to followers, and an increase in INS has emerged from leaders to followers compared to followers to leaders (Sänger et al., 2012, 2013; Jiang et al., 2015).

Also, an increased neural and bodily attunement, demonstrated by the use of gestures, has emerged between leaders and followers assigned a priori during social interactions (Yun et al., 2012; Jiang et al., 2015).

These different applications of hyperscanning within the organizational context open the way to other possible uses of this paradigm for the investigation of different processes and behaviors related to work performance, such as proactive and social resources, useful for implementing more functional strategies for corporate performance (Ingusci et al., 2019; Kim and Beehr, 2020).

Indeed, the increase in individuals' proactive behavior and social relationships could enhance job redesigns' strategies, such as job crafting, with positive effects on workers' well-being (Kim and Beehr, 2020). Furthermore, hyperscanning could prove useful for investigating moral decision-making that appears to have a strong influence on organizational functioning and well-being (Balconi and Fronda, 2019).

GESTURE SYNTHONIZATION IN FUNCTIONAL COMMUNICATION

Besides observing the mechanisms of brain areas' synchronization and coupling, some studies have shown asymmetric synchronization mechanisms within dyads composed by leader and follower (Dumas et al., 2012; Konvalinka et al., 2014; Balconi et al., 2020). In particular, this asymmetry has been defined, on one side, as functional connectivity, or a partial mechanism of directed coherence between different cerebral regions, as demonstrated by an increase of activation of the prefrontal areas for leader compared to that of ACC/parietal areas of his partner during a card game; on the other side, this asymmetry can be defined as a direct phase of coupling that occur in the activity of frontal alpha frequency band of the brain of leaders to those of the followers (Sänger et al., 2013; Konvalinka et al., 2014). However, no clear evidence has yet emerged on how these phase-connectivity patterns can be configured as a social interaction brain mechanism and how they can be linked to the difference in movement initiation timing.

Our daily social life is characterized by the performance of joint actions, during which we adjust our actions with that of other people according to what is required by different tasks (Zhou et al., 2016). These dynamic adaptations of motor behavior between interagents' individuals during joint actions have been demonstrated by different behavioral studies (Konvalinka et al., 2010; Noy et al., 2011; Zhou et al., 2016). In particular, these adaptation mechanisms are based on a cycle of action and perception (Hari and Kujala, 2009; Zhou et al., 2016) that allows to conduct suitable actions and understand that of others' individuals. Different social cognition studies have paid attention to interacting individuals, thanks to the development of hyperscanning methods using fMRI (Montague et al., 2002; Scholkmann et al., 2013). In particular, Zhou et al. (2016) have analyzed the activity of alpha (7–13 Hz) and beta (13–25 Hz) frequency bands in the sensorimotor cortices, considering their role in the processes of action execution and observation (Hari et al., 1998; Caetano et al., 2007).

In addition, the cerebral mechanisms underlying leadership have been observed by the implementation of a recent fMRI study that required participants a tapping task, including an adaptive stimulus (Fairhurst et al., 2014; Konvalinka et al., 2014). From this study emerged that the management and the perception of leadership appear to be correlated with an increase of activity in right frontal cerebral areas, more involved in self-initiated action.

In particular, this study wanted to implement a two-brain analysis capable of reporting useful characteristics to follow or conduct the behavior of two individuals involved in a realistic dyadic interaction. The use of body movements, indeed, characterizes social exchanges, as happens in gesture communication in which different types of gestures are associated with the transmission of different information (Balconi et al., 2020). In particular, in our recent study, the brain and peripheral tuning mechanisms involved in the observation and reproduction of affective, social and informative positive and negative gestures have been observed during a non-verbal communicative exchange between two subjects. The results of the study revealed an increase in inter-cerebral connectivity in specific brain areas. In particular, regarding hemodynamic activity, an increase in oxygenated hemoglobin (O2Hb) inter-cerebral connectivity in the dorsolateral prefrontal cortex (DLPFC) was observed during the observation of affective gestures and in the superior frontal convolution (SFG) during the reproduction and observation of social gestures. In addition, an increase in O2Hb and inter-brain connectivity in the left side of the DPLFC was observed during the observation of positive gestures. Regarding electrophysiological activity, an increase of inter-brain connectivity for alpha, delta, and theta frequency bands was observed in frontal cerebral regions for affective and social gestures and in posterior cerebral regions for informative ones (Balconi and

Fronda, 2020). At autonomic level, an increase of tuning in electrodermal response (level and conductance response, SCL, SCR) has emerged during the observation of negative social and affective gestures.

DISCUSSION

Therefore, hyperscanning allows exploring interpersonal brain mechanisms generated by social interactions, such as those generally represented in organizations. The mutual adaptation, as shown by brain-to-brain and body-to-body coupling of two or more interactive subjects, results in brain synchrony, which is considered the basic neurophysiological counterpart of functional mutual inter-relationships.

AUTHOR CONTRIBUTIONS

MB wrote the first draft and each section of the manuscript. MB and GF contributed to manuscript final writing and revision, read, and approved the submitted version. Both authors contributed to the article and approved the submitted version.

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

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frontiers in Psychology

ORIGINAL RESEARCH
published: 08 January 2021
doi: 10.3389/fpsyg.2020.609538

The Effect of Reviewers' Self-Disclosure of Personal Review Record on Consumer Purchase Decisions: An ERPs Investigation

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Personal review record, as a form of personally identifiable information, refers to the past review information of a reviewer. The disclosure of reviewers' personal information on electronic commerce websites has been found to substantially impact consumers' perception regarding the credibility of online reviews. However, personal review record has received little attention in prior research. The current study investigated whether the disclosure of personal review record influenced consumers' information processing and decision making by adopting event-related potentials (ERPs) measures, as ERPs allow for a nuanced examination of the neural mechanisms that underlie cognitive processes. At the behavioral level, we found that the purchase rate was higher and that the reaction time was shorter when the review record was disclosed (vs. when it was not), indicating that the disclosed condition was more favorable to the participants. Moreover, ERPs data showed that the disclosed condition induced an attenuated N400 component and an increased LPP component relative to the undisclosed condition, suggesting that the former condition gave rise to less cognitive and emotional conflict and to more positive evaluations. Thus, by elucidating potential cognitive and neural underpinnings, this study demonstrates the positive impact of reviewers' disclosure of personal review record on consumers' purchase decisions.

Keywords: review record, self-disclosure, purchase decision, event-related potentials, N400, LPP

OPEN ACCESS

Edited by:
Tao Liu,
Zhejiang University, China

Reviewed by:
Wei Fan,
Hunan Normal University, China
Lian Duan,
Shenzhen University, China

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *23 September 2020*
Accepted: *09 December 2020*
Published: *08 January 2021*

Citation:
Liu J, Mo Z, Fu H, Wei W, Song L and Luo K (2021) The Effect of Reviewers' Self-Disclosure of Personal Review Record on Consumer Purchase Decisions: An ERPs Investigation. Front. Psychol. 11:609538. doi: 10.3389/fpsyg.2020.609538

INTRODUCTION

In the current era of electronic commerce, online consumer reviews (OCRs) serve as principle cues for consumer decision making and attract much scholarly attention (Reyes-Menendez et al., 2019b). Previous work on OCRs has documented that the credibility of OCRs positively affects consumer purchasing of recommended products (Cheung et al., 2009; Yan et al., 2016, 2018; Grewal and Stephen, 2019). To lower the risks of purchasing products on electronic platforms, consumers generally resort to OCRs with a high level of credibility when making purchase decisions (Riley et al., 1954; Mcknight and Kacmar, 2006; Park et al., 2014). However, given that OCRs are posted online by strangers in most cases and that large volumes of OCRs are available, it is challenging for consumers to assess the credibility of OCRs (Metzger, 2007; Cheung and Thadani, 2012; Park et al., 2013; Reyes-Menendez et al., 2019a). Consequently, consumers have to exploit online informational cues in order to make credibility evaluations.

Several reviewer factors have been confirmed to influence the credibility and helpfulness of OCRs, including reviewer ranking (Baek et al., 2012), reviewer cumulative helpfulness (Cao et al., 2011), reviewer reputation (Racherla and Friske, 2012) and reviewer personal information disclosure (Xie et al., 2011). Among these factors, reviewer self-disclosure is an intriguing issue that has received increasing levels of attention from academics and practitioners. Self-disclosure is generally defined as "any information about himself which Person A communicates verbally to a Person B" (Riley et al., 1954; Cozby, 1973). In computer-mediated contexts, posting one's personal information online is a typical means of self-disclosure. With the aid of personally identifiable information, a consumer is able to distinguish a reviewer from others online (Tidwell and Walther, 2002). In fact, it has been established that reviewers' self-disclosure has a positive impact on consumers' perception of source credibility, which in turn shapes consumer willingness to accept certain messages as well as their willingness to buy the product (Forman et al., 2008; Cox et al., 2009; Yoo et al., 2009; Xie et al., 2011). For example, Xie et al. (2011) reported that the presence of online reviewers' personally identifiable information positively affect consumers' perceived credibility of ambivalent online hotel reviews and hotel booking intentions.

Extant OCRs-related research has identified reviewers' names, geographic locations, interests and profile pictures as main types of personal information (Forman et al., 2008; Xie et al., 2011). Some online shopping websites, such as Amazon.com, also display the reviewers' personal review records alongside with other personal information. Personal review record, also known as personal review history, refers to the entire past review information of a reviewer. If a reviewer chooses to disclose his (or her) personal review record, other consumers are able to see all the product reviews he has posted before. Though prior research has endeavored to seek out how the disclosure of personally identifiable information (e.g., profile picture, name and geographic location) affects perceived source credibility and consumer purchase decision (Lee and Shin, 2014; Xu, 2014; Liu and Park, 2015; Karimi and Wang, 2017), the disclosure of personal review record, however, has received little attention. Hence the present work is aimed to uncovering the effect of the disclosure of personal review record on consumers' responses.

Information signaling theory, which has been applied to elucidate how consumers rely on various signals to form expectations about quality, is helpful in understanding the abovementioned effect. In online environment, the quality of products and services are generally difficult to evaluate due to information asymmetry (Akerlof, 1970). Signaling theory provides a framework to understand the various types of signals that are used to reduce information asymmetry and the situations in which they are used (Mavlanova et al., 2012). According to signaling theory, signals are observable and alterable attributes which can be used by individuals or organizations to communicate hidden or limited quality information to consumers to promote a purchase or transaction (Wells et al., 2011). Signals are particularly important in online contexts, because online contexts generally involve a higher level of uncertainty and risk than offline contexts (Mitra and Fay, 2010). Since OCRs are posted mostly by strangers online, it is difficult for potential consumers to assess the credibility of OCRs. Thus, consumers resort to any signals about the reviewer to aid their assessment of source credibility and message quality (Naujoks and Benkenstein, 2020). For instance, Le et al. (2018) demonstrated that source expertise signal was positively associated with perceived message quality. In the current study, the disclosure of personal review record might be seen by the potential consumers as a signal sent by the reviewer to show that his reviews are open to social scrutiny and are of high quality and credibility (Kirmani and Rao, 2000). Additionally, the disclosure of personal review record might also signal that the reviewer's identity could be distinguished from the others in the online context. Hence we assumed that it would result in a notable increase in consumer behavioral intention when the reviewer's personal review record was disclosed (vs. not disclosed). To the best our knowledge, this is the first study to conceptualize personal review record as a signal that influences consumer decision.

In recent years, the rapid advance in neuroscience has made it possible to incorporate event-related potentials (ERPs) technique into marketing related research. Changes in electrophysiological brain signals have been demonstrated to be useful for examining the perceptual and cognitive processes that occur in response to marketing stimuli (Ma et al., 2018). As a result, ERPs were adopted to examine the effect of the disclosure of personal review record on consumer purchase decision making. In the experiment, personal review record was set as either visible or invisible. Specifically, in the disclosed condition, an information cue indicating the disclosure of personal review record was provided whereas in the undisclosed condition, an information cue indicating the nondisclosure of personal review record was provided. In line with previous studies on consumer decision making, we mainly focused on N400 and late positive potential (LPP) components (Wang et al., 2015; Goto et al., 2017; Jin et al., 2017).

Generally, N400 is a negative deflection that mainly arises at approximately 400 ms post stimulus presentation in the frontal and central areas of the brain (Steffensen et al., 2008; Chen et al., 2010; Wang et al., 2015). Although N400 component is traditionally conceptualized as an indicator of semantic violations, it is also suggested to be an indicator of non-semantic conflict by recent research (Chen et al., 2010; Huang et al., 2014). In fact, semantic conflict can be viewed as a special case of informational conflict (Wang et al., 2015). It has been established that when a stimulus provides varied conflict information, a salient N400 component might be elicited, which suggests the occurrence of a phase of conflicting information processing when consumers are faced with incongruent extrinsic cues (Ma et al., 2014; Wang et al., 2015). In the current study, subjects might face more uncertainty regarding the authenticity of the product review in the undisclosed condition, which may denote the occurrence of higher levels of cognitive and emotional conflict when consumers are making purchase decisions. Therefore, we expected the undisclosed condition to induce a more negative N400 than the disclosed condition.

Belonging to the P300 family, LPP is a positive-going component that typically peaks at roughly 600 ms after the stimulus onset and lasts for a long duration (Schupp et al., 2000). LPP is widely distributed from the anterior regions to the posterior regions. Past research consistently suggests that the LPP component indicates the allocation of attentional resources to stimuli (Ito and Cacioppo, 2000; Langeslag et al., 2007; Qin and Han, 2009; Wang et al., 2015). LPP is also indicative of the evaluative categorization process before a final purchase decision is made, such that a more pronounced LPP amplitude would be induced by a more desirable stimulus than a less desirable one (Wang et al., 2015; Jin et al., 2017). In the current study, participants exposed to different extrinsic cues might also undergo an evaluative process of categorization. In contrast to the undisclosed condition, the disclosed condition was more preferable for the subjects because it signaled a higher level of credibility. Hence, we hypothesized that the disclosed condition would elicit an enlarged LPP amplitude relative to the undisclosed condition.

MATERIALS AND METHODS

Participants

Thirty-five right-handed undergraduate students were recruited as paid volunteers. All participants had either normal or corrected-to-normal visual acuity and did not have any history of neurological or psychiatric disorders. The experiment was approved by the Internal Review Board of the Laboratory of Neuromanagement and Decision Neuroscience of Guangdong University of Technology. In accordance with the Declaration of Helsinki, written informed consent was obtained from each participant before the experiment. Data from two participants were discarded due to excessive artifacts, leaving thirty-three valid participants (16 females) aged 17–24 ($M \pm SD = 19.15 \pm 1.25$). A power analysis was performed to determine the sample size prior to the experiment. The suggested sample size was 14 when we assumed the effect size (f) to be 0.2 and the error probability (α) to be 0.05. Thus, the sample size of the current study fully met the requirement.

Stimuli

Eighty T-shirts with similarly attractive appearance were selected from JD.COM, one of the most popular online B2C websites in China. Those 80 pictures were randomly assigned to the disclosed condition and the undisclosed condition. Twenty-two respondents who didn't participate in the formal experiment were asked to rate the attractiveness, familiarity and complexity of each T-shirt on seven-point Likert scales ranging from 1 (very low) to 7 (very high). Paired *t*-tests showed that the attractiveness [$M_{disclosed} = 4.50$, $SD = 0.67$; $M_{undisclosed} = 4.62$, $SD = 0.85$; $t(21) = -1.014$, $p = 0.322$], familiarity [$M_{disclosed} = 5.35$, $SD = 0.79$; $M_{undisclosed} = 5.31$, $SD = 0.81$; $t(21) = 0.660$, $p = 0.516$] and complexity [$M_{disclosed} = 3.38$, $SD = 0.46$; $M_{undisclosed} = 3.42$, $SD = 0.41$; $t(21) = -0.75$, $p = 0.462$] did not differ between the disclosed condition and the undisclosed condition. Moreover, a group interview of students at Guangdong University of Technology was held to identify product ratings that were thought to be acceptable when purchasing a product. Product ratings refer to the aggregated review ratings computed according to all review ratings posted by consumers who have purchased the product. The five star rating system is widely used by electronic commerce websites, with one star (corresponding to 1.0) signaling the lowest score and five star (corresponding to 5.0) signaling the highest score. The result revealed that product ratings ranging between 4.1 and 5.0 were acceptable. Therefore, each product was paired with a product rating between 4.1 and 5.0, while the ratings remained consistent across experimental conditions. The disclosure of personal review record was manipulated by using information cues. In the disclosed condition, the cue "visible" was provided to indicate the disclosure of personal review record; while in the undisclosed condition, the cue "invisible" was provided to indicate the nondisclosure of personal review record. There were 40 trials in each condition and 80 trials in total.

Procedure

During the experiment, participants were comfortably seated in a dimly lit and sound proof room. The experimental procedure was introduced on paper handouts and exemplars of detailed personal review records were shown to the participants. Each participant completed eight practice trials to become familiar with the task before the formal experiment. As is shown in **Figure 1**, each trial began with a fixation cross appearing in the center of a screen for 1,000 ms, which was followed by the presentation of an image of a T-shirt (S1, 4.5° × 6.0° visual angle) for 1,000 ms. This was followed by an interval with a random duration of 400–600 ms, after which a stimulus containing both product rating and personal review record information (S2, 2.1° × 2.4° of visual angle) was shown for 3,000 ms. The participants were asked to determine whether to buy the product as soon as possible within 3,000 ms. Keypads were used to provide responses and response-to-hand assignments were counterbalanced across the participants. To eliminate the potential influence of reading order, the relative positioning of product ratings and personal review record cues was counter-balanced. S2 was then followed by an inter-trial interval of 800 ms. There were four blocks and the ordering of trials was randomized within each block. Stimulus presentation and behavioral data recording were controlled using E-Prime 2.0 software (PST, Psychology Software Tools Inc.). The EEG experiment took about 15 min, including break time between blocks.

After completing the EEG experiment, the participants were asked to rate the displayed product offerings in terms of perceived disclosure, perceived trustworthiness (Flanagin and Metzger, 2016), and purchase intention (Dou et al., 2012). All ratings were made on seven-point scales (1 = "strongly disagree" to 7 = "strongly agree").

Electroencephalogram (EEG) Data Acquisition and Analysis

The electroencephalograms of the participants were recorded with an eego amplifier (ANT Neuro, Enschede, Netherlands) with

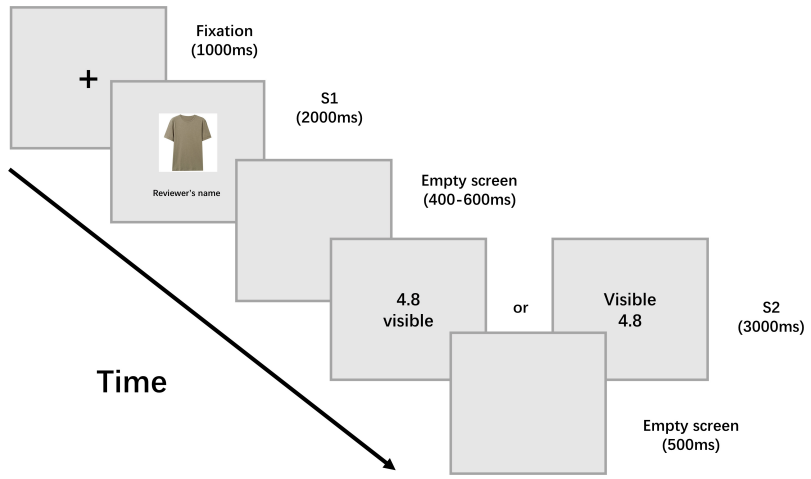

FIGURE 1 | Experimental procedure. Participants were asked to make a purchase decision after viewing the cue information (S2).

a 500 Hz sampling rate and 0.1–100 Hz bandpass. An elastic electrode cap with 64 Ag/AgCl electrodes was used and the impedances of the electrodes were maintained at below 10 kΩ throughout the experiment. A cephalic electrode placed between FPZ and FZ served as a ground electrode. The left mastoid was used as an online reference. The EEG was re-referenced offline to the average of the left and the right mastoids.

ASALab 4.10.1 software (ANT Neuro, Enschede, Netherlands) was used to process offline EEG data. An eye movement correction algorithm was used to identify and correct Ocular artifacts. Before the ERPs data were segmented into epochs, a low-pass filter at 30 Hz (24 dB/Octave) was used to filter the raw data. The epochs of the stimulus were set to 1,000 ms, with 200 ms before the stimulus onset serving as the baseline and with 800 ms occurring post-stimulus onset. Trials involving amplifier clipping, bursts of electromyography activity, or peak-to-peak deflection exceeding ± 100 V were excluded from averaging. The EEG epochs were averaged for each participant within each condition and then grand averaged. Finally, data were analyzed using within-subjects repeated-measures ANOVAs.

Based on the processed data and past research on purchase decision making (Wang et al., 2015), two ERPs components, N400 and LPP, were analyzed in this study. Six electrodes (F3, FZ, F4, FC3, FCZ, and FC4) distributed from the frontal to fronto-central regions were selected for N400 analysis. Nine electrodes (F3, FZ, F4, FC3, FCZ, FC4, C3, CZ, and C4) distributed from the frontal to central regions were selected for LPP analysis. The mean amplitude of the N400 in the time window of 445–465 ms after the onset of S2 was used in a 2 (disclosure: disclosed and undisclosed) × 6 (electrodes: F3, FZ, F4, FC3, FCZ, and FC4) repeated-measure ANOVA. Similarly, the mean amplitude of LPP in the time window of 500–650 ms was used in a 2 (disclosure: disclosed and undisclosed) × 9 (electrodes: F3, FZ, F4, FC3, FCZ, FC4, C3, CZ, and C4) repeated-measure ANOVA. The Greenhouse–Geisser correction (Greenhouse and Geisser, 1959) was applied when the sphericity assumption did not apply (uncorrected dfs and corrected *p*-values were reported).

RESULTS

Behavioral Results

The one-way repeated measure ANOVA on purchase rate revealed a significant main effect of disclosure [$F(1, 32) = 62.990$, $p < 0.001$, $\eta_p{}^2 = 0.663$]. As illustrated in **Figure 2**, the purchase rate for the disclosed condition ($M = 0.88$, $SE = 0.14$) is higher than that for the undisclosed condition ($M = 0.41$, $SE = 0.11$). Furthermore, the effect of disclosure on reaction time was also significant [$F(1, 32) = 32.803$, $p < 0.001$, $\eta_p{}^2 = 0.506$]. The disclosed condition led to a significantly shorter reaction time ($M = 940.45$ ms, $SE = 247.55$) than the undisclosed condition ($M = 1{,}090.40$ ms, $SE = 294.85$). Statistical analysis results for ratings collected after the EEG experiment are shown in **Table 1**. **Table 1** shows that perceived disclosure, trustworthiness and purchase intention were significantly higher for the disclosed condition than for the undisclosed condition.

ERPs Results

As shown in **Figure 3**, the ANOVA on N400 amplitude showed that the main effect of disclosure was marginally significant [$F(1, 32) = 3.515$, $p = 0.070$, $\eta_p^2 = 0.099$]. A more negative N400 amplitude was elicited by the undisclosed condition ($M = -1.504$ μV, $SE = 0.341$) than by the disclosed condition ($M = -0.866$ μV, $SE = 0.312$). The main effect of electrodes was significant [$F(1, 32) = 9.875$, $p < 0.001$, $\eta_p^2 = 0.236$]. The interaction effect between disclosure and electrodes was not significant.

The ANOVA on LPP amplitude revealed a significant main effect of disclosure [$F(1, 32) = 5.765$, $p = 0.022$, $\eta_p^2 = 0.153$]. The LPP amplitude in the disclosed condition ($M = -0.198$ μV, $SE = 0.034$) was larger than that in the undisclosed condition ($M = -0.852$ μV, $SE = 0.321$). The main effect of electrodes was also significant [$F(1, 32) = 14.670$, $p < 0.001$, $\eta_p^2 = 0.314$]. The interaction effect between disclosure and electrodes was not significant.

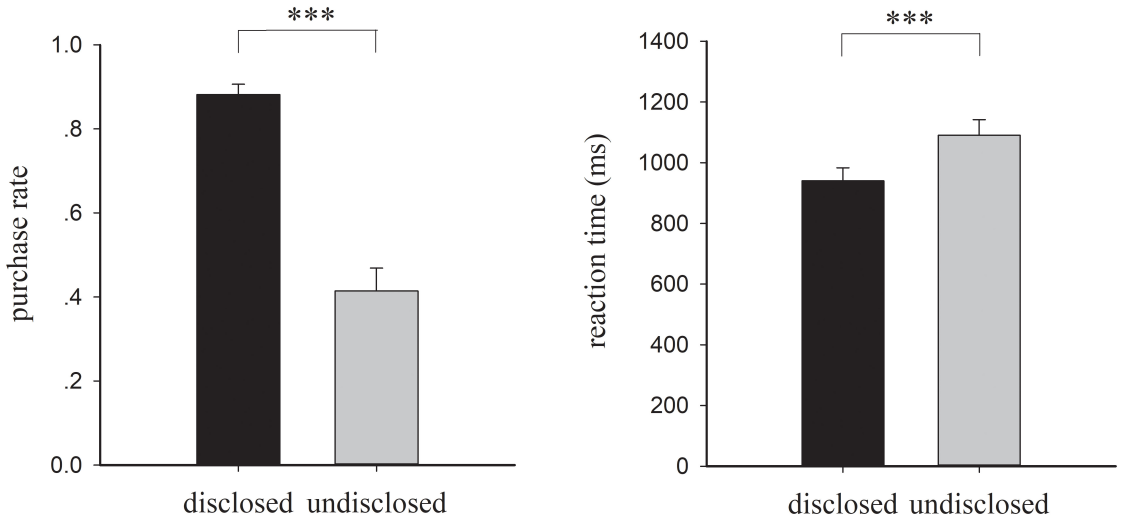

FIGURE 2 | Behavioral results. The purchase rate and reaction time for each condition are shown. Error bars denote the standard error of the mean. ***$p < 0.001$.

TABLE 1 | Statistical analysis results of the rated items.

Variables	Disclosed condition		Undisclosed condition		*F*	*p*
	M	*SE*	*M*	*SE*		
Perceived disclosure	5.64	0.69	2.24	0.93	680.353	< 0.001
Trustworthiness	5.73	0.72	2.55	0.71	289.655	< 0.001
Purchase intention	5.21	0.63	2.12	0.65	403.877	< 0.001

DISCUSSION

Given its crucial role in aiding purchase decision-making, OCRs have become very popular among online consumers. Though a lot of effort has been devoted to investigating the impact of source credibility of OCRs on consumer decisions, few studies have explored the impact of reviewer's disclosure of personal review record in this scenario. The present study is intended to investigate this issue. By engaging participants in virtual shopping tasks via the EEG method, the results may provide a nuanced understanding of consumers' online decision processes.

Behaviorally, a higher purchase rate was observed in the disclosed condition than the undisclosed condition. Since the same product ratings were assigned to different experimental conditions, any differences in consumer decisions could not be attributed to product ratings. The finding that participants were more likely to buy a T-shirt when they noticed that the personal review record was disclosed was consistent with previous studies on reviewer identity disclosure and purchase decisions (Cox et al., 2009; Xie et al., 2011). This choice phenomenon could be explained from the perspective of signaling theory (Akerlof, 1970; Kirmani and Rao, 2000). Different parties in a market interaction often have different amount of information. More specifically, though reviewers know the credibility of their reviews, consumers are not fully informed of the credibility of the reviews. Therefore, quality signaling is used to communicate hidden or limited quality information to potential consumers to overcome information asymmetry (Wells et al., 2011). By disclosing the personal review record in the online environment, the reviewer sent a signal to the potential consumers that his reviews were open to social scrutiny and that his personal identity was identifiable. Consequently, participants inferred a higher level of perceived trustworthiness (a sub-dimension of credibility) when the personal review record was disclosed than when it was not (Chesney and Su, 2010), as was indicated by the rating results collected after the EEG experiment. A higher level of perceived credibility further gave rise to a higher purchase likelihood in the disclosed (vs. undisclosed) condition, which coincided with prior research (Forman et al., 2008; Xie et al., 2011; Priester and Petty, 2016).

Moreover, less time was spent making decisions in the disclosed condition (vs. undisclosed condition). Previous studies have revealed that task completion times (i.e., RTs) are positively correlated with task difficulty and cognitive load, as the more difficult a task is, the more RT it takes to complete (Sweller, 1988; Wang et al., 2015). Consistent with previous studies, we found longer RTs in the undisclosed condition than the disclosed condition, which indicated that less cognitive effort was required for participants' decision making in the disclosed condition (vs. the undisclosed condition). Compared to the undisclosed condition, the disclosed condition was more favorable to the participants, which promoted decision making.

In line with the behavioral pattern, an attenuated N400 component and an increased LPP component were observed

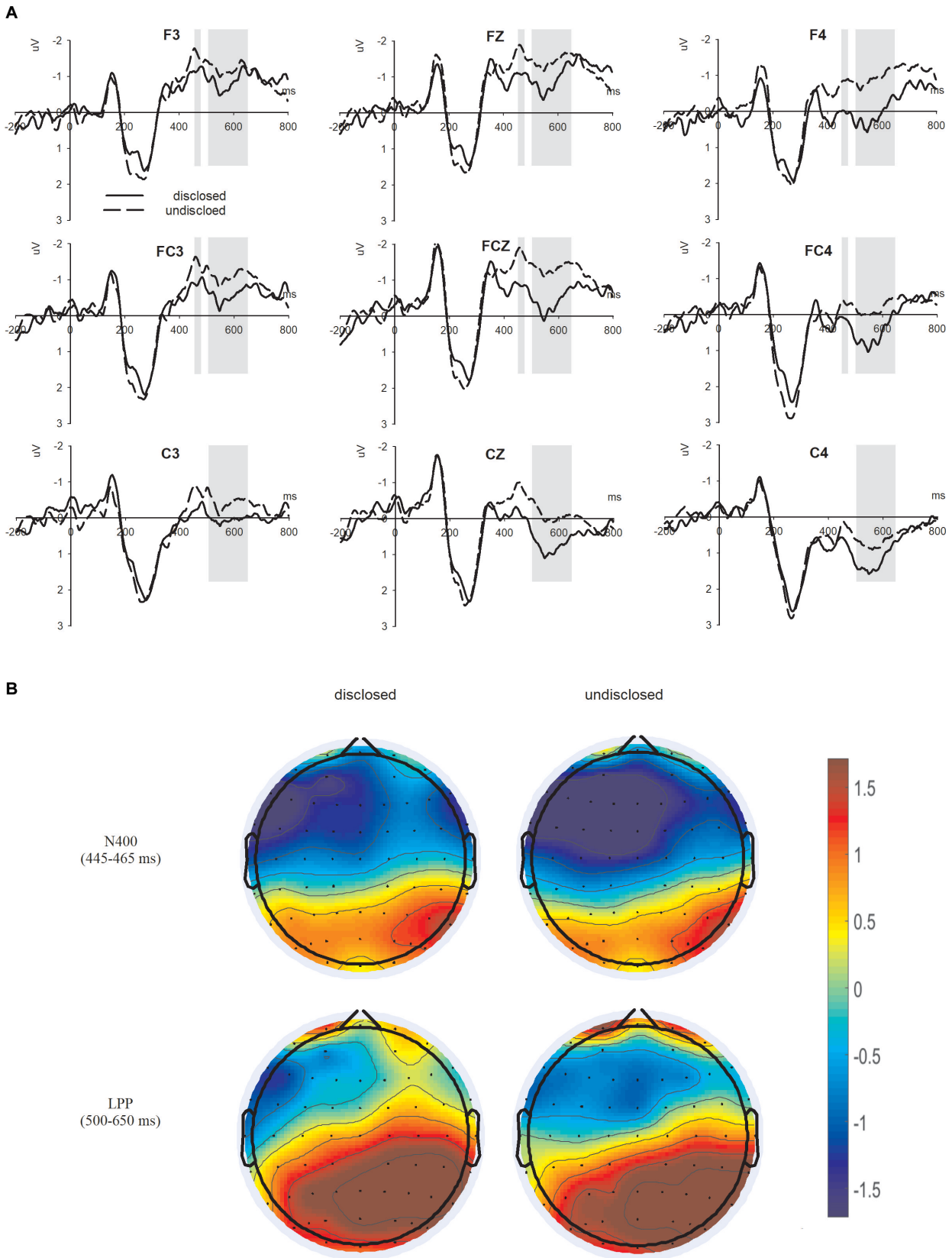

FIGURE 3 | ERPs results. **(A)** the grand average waveforms at nine electrodes. **(B)** The topographic distributions of the waves of N400 and LPP.

in the disclosed condition (vs. the undisclosed condition). Dozens of studies have shown that N400 is related to semantic conflict (Steffensen et al., 2008; Kutas and Federmeier, 2011). However, recent research in neuromarketing has found that N400 and N400-like components might serve as indicators of cognitive and emotional conflict (Steffensen et al., 2008; Chen et al., 2010; Wang et al., 2015; Shan, 2016). For example, Chen et al. (2010) defined a conformity condition whereby a consumer buys a product when presented with consistently positive reviews and does not buy a product when presented with consistently negative reviews, and a counter-conformity condition whereby a consumer does not buy a product when presented with consistently positive reviews and buys a product when presented with consistently negative reviews. The authors found that the counter-conformity condition evoked a larger N400-like component than the conformity condition, suggesting that participants experienced stronger cognitive and emotional conflicts when making a counter-conformity purchase decision. The higher the level of conflict, the larger the N400 amplitude. Furthermore, Wang et al. (2015) noted that products presented under conflictive conditions (high rating and low sales, and low rating and high sales) evoked larger N400 amplitudes than those presented under consistent conditions (high rating and high sales, and low rating and low sales), which suggested that the conflictive conditions led to more cognitive and emotional conflict and required more cognitive control. In the current study, as evidenced by the trustworthiness ratings collected after the EEG experiment, the invisibility of personal review record induced a higher level of uncertainty about the reviewer's identity and a lower level of credibility, which might arouse heightened conflict processing. As a result, the enlarged N400 component observed in the undisclosed condition (vs. the disclosed condition) suggests that the undisclosed condition leads to more cognitive and emotional conflict and requires more cognitive control.

LPP is a well-established ERPs component that is indicative of evaluation and categorization and sensitive to both explicit and implicit categorization (Ito and Cacioppo, 2000; Wang et al., 2015). Importantly, recent research on neuromarketing has uncovered a close association between LPP component and evaluative categorization at the late cognitive processing stage (Wang et al., 2015; Jin et al., 2017). In the current study, the discrepancy in LPP amplitudes suggests that the disclosed condition is classified as being more favorable to the participants. Category similarity has been found to be crucial during evaluative categorization. More attentional resources will be allocated and a larger LPP component will be elicited when the presented category is close to the favorable target category (Fu et al., 2019). In the current study, participants formed expectations about the favorable characteristics of a reviewer and adopted the disclosed condition as a criterion category because it signaled high source credibility. During the task, the presented personal review record cue was automatically compared to the criterion. Hence, amplitudes of LPP were found to be larger in the disclosed condition than in the undisclosed condition. The behavioral data also support this interpretation. On the one hand, participants showed a higher purchase rate and faster reaction time in the disclosed condition. On the other hand, participants rated higher perceived trustworthiness in the closed condition. Taken together, the LPP result might imply the consumers' evaluative categorization process at the late cognitive processing stage.

Theoretical and Practical Implications

Theoretically, this research represents one of the first studies to contribute insight into the role of personal review record in consumer behavior. Though prior research has devoted a lot of attention to reviewer's self-disclosure, the disclosure of personal review record has remained underexplored. This research bridges the gap in the literature. Moreover, this research complements extant literature on signaling theory. To the best of our knowledge, this is the first study to conceptualize the disclosure of personal review record as a signal that could be used to assure the consumers of the reviewer's credibility. Specifically, compared with a reviewer who does not disclose his (or her) personal review record, a reviewer who does leads to a higher level of perceived trustworthiness and greater willingness to purchase the reviewed product. Finally, our findings also extend extant research on neuromarketing. By combining behavioral and ERPs approaches, this study provides a nuanced understanding of how self-disclosure of personal review record influences consumer information processing and decision-making.

Our study also has practical implications for online shopping platform operators, marketers, and consumers. The findings of the present study suggest that the disclosure of reviewers' personal review record could enhance the perceived credibility of product reviews, which will ultimately influence the persuasiveness of reviews and lead to an increase in purchase rate. From this point of view, this study may serve as a reference for online information presentation. An absence of personal review record on e-commerce platforms (e.g., Taobao.com) might significantly reduce the perceived credibility of reviews, which might in turn lower consumers' purchase intentions. Alternatively, reviewers may disclose identity information to enhance others' perceived credibility of their reviews. Hence, it's highly recommended that e-commerce platforms establish mechanisms that encourage reviewers to disclose their identity information to potential consumers who turn to reviews for shopping guidance, which will finally promote the development of electronic commerce.

Limitations and Future Research

Although this study offers some interesting findings, there are some limitations worth highlighting for future research. First, this study is focused on only one type of product (T-shirts). We chose T-shirts as the products because most people are familiar with T-shirts and they have been frequently used in prior neuromarketing research (Yokoyama et al., 2014; Shang et al., 2017). T-shirts are relatively inexpensive and belong to utilitarian products. A replication of the study based on a wider range of products (e.g., expensive or hedonic products) could be conducted to generalize the findings of the present study. Second, the results only showed a marginally significant effect of disclosure on N400 when we selected six electrodes

(F3, FZ, F4, FC3, FCZ, and FC4) for N400 analysis. We surmise that it might not be due to the sample size because the power analysis suggested that the sample size of the current study met the requirement. In fact, though we didn't find an interaction between disclosure and electrodes on N400, the effect of disclosure on N400 turned out to be statistically significant ($p = 0.043$) when we selected four electrodes in the middle and right scalp regions (FZ, F4, FCZ, and FC4) for N400 analysis. Consequently, we speculate that the conflict information may be processed mainly in the middle and right scalp regions in the present study. Further studies are required to confirm this point. Third, as an exploratory study, only information cues were used to signal if the personal review record was disclosed in order to eliminate possible confounding factors. Future research may adopt more vivid presentation of personal review record.

CONCLUSION

In summary, through this study we investigated the effect of reviewers' self-disclosure of personal review record on consumers' purchase decision making and the underlying neural substrates. Behaviorally, the disclosed condition led to higher purchase rates and shorter reaction times. The electrophysiological results showed an attenuated N400 and an enlarged LPP for the disclosed condition (vs. the undisclosed condition), indicating that the disclosed condition resulted in less conflict and more positive evaluations. In line with source credibility theory and signaling theory, the results suggest that the disclosure of personal review record could enhance the perceived trustworthiness of reviews and help consumers make purchase decisions. The findings of the current research contribute to the self-disclosure literature by uncovering the effect of personal review record.

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 the Internal Review Board of the Laboratory of Neuromanagement and Decision Neuroscience of Guangdong University of Technology. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JL and HF conceived and designed the study, interpreted the data, and drafted the manuscript. JL collected and analyzed the data. JL, ZM, HF, WW, LS, and KL reviewed and edited the manuscript. HF administered the project. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by the Philosophy and Social Sciences Foundation of Guangdong Province (No. GD19CGL09), the Natural Science Foundation of Guangdong Province (No. 2017A030310466), the Humanities and Social Sciences Foundation of the Ministry of Education of China (No. 18YJC630034), and the National Natural Science Foundation of China (No. 71972052).

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

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frontiers in Psychology

ORIGINAL RESEARCH
published: 11 January 2021
doi: 10.3389/fpsyg.2020.579459

The Neuroscience of Organizational Trust and Business Performance: Findings From United States Working Adults and an Intervention at an Online Retailer

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This paper reports findings from a nationally representative sample of working adults to quantify how a culture trust improves business performance. Analysis of the national sample showed that organizational trust and alignment with the company's purpose are associated with higher employee incomes, longer job tenure, greater job satisfaction, less chronic stress, improved satisfaction with life, and higher productivity. Employees working the highest quartile of organizational trust had average incomes 10.3% higher those working in the middle quartile of trust (p = 0.000) indicating that trust increases productivity. In order to demonstrate the causal effect of trust on business performance, we created an intervention to increase organizational trust in a division facing high job turnover at a large online retailer. The intervention increased organizational trust by 6% and this improved job retention by 1%. These studies show that management practices that increase organizational trust have salubrious effects on business performance.

Keywords: job satisfaction, employee well-being, discretionary effort, neuromanagement, organizational culture

OPEN ACCESS

Edited by:
Vincenzo Russo,
Università IULM, Italy

Reviewed by:
Maria Elisa Maiolo,
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Carlo Galimberti,
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *02 July 2020*
Accepted: *11 December 2020*
Published: *11 January 2021*

Citation:
Johannsen R and Zak PJ (2021) The Neuroscience of Organizational Trust and Business Performance: Findings From United States Working Adults and an Intervention at an Online Retailer. Front. Psychol. 11:579459. doi: 10.3389/fpsyg.2020.579459

INTRODUCTION

Peter Drucker challenged traditional labor economics by arguing that "knowledge workers" (Drucker, 1988, p. 3) have significant power when choosing for whom they work, where they work, and what they work on (Drucker, 1988). At the time of Drucker's writing, and even today, many companies de-motivate their "human capital" by treating them like capital rather than humans. Traditional labor economics presumes that work provides disutility and therefore employees are expected to shirk whenever possible (Spencer, 2015). Companies that design management processes assuming there is this conflict between employees and supervisors often create such conflicts.

The traditional labor economics view runs counter to an accumulation of evidence showing that human-centric organizations have higher productivity and lower job turnover rates (Rastogi, 1986; Vandenberghe, 1999; Hall and Yip, 2016; Jena et al., 2018). Companies have discovered that employees often quit to take jobs that are more creative, exciting, and energizing (Bersin, 2014). Turnover is a particularly expensive problem as most jobs require firm-specific skills that cannot be transferred and can take years to cultivate (Bersin, 2014). Unlike machinery, people can exert discretionary effort if motivated to do so. Beyond monetary compensation, many colleagues desire autonomy, honesty, appreciation, and work that has a positive impact on their communities (Zak, 2017).

These conditions are part of a company's "culture" defined as a set of employee behaviors that occur at work (Deloitte., 2014). Often, companies write mission statements, bring in

designers to create interesting work spaces, and create recognition programs in order to establish an organizational culture without having clear guidance on which aspects of culture create value; value both from the employee's perspective and for the organization as a whole. Culture is often ignored because it seems ambiguous or difficult to manage. We propose herein that a set of behaviors that create trust between work colleagues is an aspect of organizational culture that improves business outcomes including productivity, job satisfaction, turnover, and well-being. We also show that organizational trust can measured and managed like other business process.

THEORY

Organizational Trust and Oxytocin

The motivation for our focus on organizational trust is research showing that countries with high generalized trust have faster income growth than low trust countries. Trust reduces transaction costs and thereby facilitates wealth creation (Zak and Knack, 2001; Slemrod and Katuscak, 2005; Pucetaite and Lamsa, 2008; Dincer and Uslaner, 2010; Bjornskov, 2012; Kong, 2013). Interpersonal trust also contributes to individual well-being by facilitating secure attachments to others (Zak, 2017; Zak and Fakhar, 2006; Slemrod and Katuscak, 2005). Yet, little is known about the effects of organizational trust on business performance. On a national level, generalized trust is high when formal and informal institutions function efficiently and fairly, when income distribution is relatively equal, and when incomes are high (Zak and Knack, 2001). These factors can be changed through policies, often producing a positive return on the cost of policy changes by generating faster income growth (Knack and Zak, 2003; Slemrod and Katuscak, 2005). Similar to citizens in a country who interact and trade with each other, workplace colleagues interact with each other repeatedly, and the quality of these interactions is affected by the organization's culture; that is, its formal and informal institutions. The types of colleague interactions may build or degrade trust.

When seeking to understand how trust varies in organizations, we drew on research showing that the neurochemical oxytocin (OT) is released in the brain after positive interactions with others, including strangers, and signals that the other person appears to be trustworthy (Zak et al., 2004, 2005, 2008; Morhenn et al., 2008; Barraza and Zak, 2013; Zak and Barraza, 2013; reviewed in Zak, 2012). Infusing synthetic OT into human brains substantially increases trust in a sequential dyadic money transfer task (Kosfeld et al., 2005), increases generosity and charity (Zak et al., 2007; Barraza et al., 2011), and can help rebuild trust after a breach (Baumgartner et al., 2008). The neuroscience research shows that OT binding to neurons in the subgenual cortex stimulates the release of midbrain dopamine (Love, 2014). This means that being trustworthy makes people feel good and when this happens at work, work itself may be enjoyable. The types of prosocial behaviors that induce OT release are found in employees who are good organizational citizens (Battistelli et al., 2013; Steger et al., 2012). Organizations that create work environments that stimulate OT production among colleagues are expected to have high-trust cultures.

Our group ran laboratory experiments to assess how positive and negative citizenship behaviors in simulated work settings affected neurophysiology, motivation, and productivity (Alexander et al., 2018; Terris et al., 2018; Kraig et al., 2019; Johannsen and Zak, 2020). We then gained permission from a set of businesses and nonprofit organizations to measure employees' neurophysiology, motivation, and productivity in their workplaces (Zak, 2017). We combined these findings with a review of the literature indicating ways that social interactions stimulate the brain to produce OT. We used all this information to identify eight behaviors that organizations can influence that may affect organizational trust ("Trust" herein). To make these easier to remember, we created an acronym OXYTOCIN to represent them; this stands for Ovation, eXpectation, Yield, Transfer, Openness, Caring, Invest, and Natural. A definition of each and brief rationale for inclusion are presented next, while a full explanation and justification can be found elsewhere (Zak, 2017).

The first factor, Ovation celebrates the contributions of high performers. When Ovation is close in time to when a goal is met, is public, comes from peers, is tangible and unexpected, then the likelihood and magnitude of OT release are higher than when recognition does not have these aspects (Zak, 2018). The second component, eXpectation gives colleagues concrete, difficult but achievable goals. Such goals typically require that colleagues draw on the social resources at work, increasing the chances for OT release (Barraza and Zak, 2009; Zak, 2018). Yield empowers colleagues to execute projects as they see fit, increasing ownership over outcomes (Argyris, 1976; Stajkovic and Luthans, 1998; Kirkcaldy et al., 2002; Campbell et al., 2011). This demonstrates trust by a supervisor who must provide consistent feedback so projects stay on track. When feedback is positive, OT release is likely. Transfer allows colleagues to job-craft by choosing the tasks, projects, work location, and hours they prefer (Deci and Ryan, 2000; Katz and Krueger, 2017). This signals trust while holding colleagues accountable to reach goals. Openness about the organization's goals and the reasons for management decisions reduces the stress colleagues absorb on the job and thereby increases the brain's ability to produce OT (Pucetaite and Lamsa, 2008; Zak, 2018). Caring creates opportunities for colleagues to intentionally build relationships with each other, stimulating OT release and enhancing teamwork (Alexander and Zak, 2015). A culture of Invest expends resources to stimulate colleague professional and personal growth (Ryff and Keyes, 1995). This shows the organization expects the employee to remain on the job at least in the medium term since it is providing opportunities for growth. Lastly, Natural is trustworthy behavior by leaders. When trust is modeled by those in charge, others tend to follow, and reciprocal OT release is likely to occur (Zak et al., 2004, 2005; Sendjaya and Pekerti, 2010).

We tested the validity of these factors by returning to workplaces and inviting employees take the survey we had developed. This provided preliminary evidence that the OXYTOCIN factors captured behaviors that contribute to organizational trust.

Purpose

There are at least two types of purpose in organizations. The first is transactional purpose, the processes built to execute the generation of revenue and to pay expenses (Daft, 2016). Here we will focus on a second type that follows from work by Peter Drucker, W. Edwards Deming and others who argue that the purpose of an organization is to improve the lives of its employees and customers (Drucker, 1993/1946, 2007/1955; Deming, 1994; Steger et al., 2012; Deloitte., 2014). We will call this aspect of an organization its transcendent purpose (denoted "Purpose"). Purpose is necessarily other-focused, invoking the inherent service to others that is at the core of all organizations. When the Purpose of an organization or task is known, then effort and productivity are higher (Chandler and Kapelner, 2013; Brown et al., 2015). While Trust captures the dynamics of team interactions, Purpose tells the team why it is going forward. Without the who and why in place, team performance suffers (Kirkman and Rosen, 1999; Zak, 2018; Fahn and Hakenes, 2019). Organizations with understood and lived Purposes have higher retention and are more profitable (Harter et al., 2002; Deloitte., 2014). Research from our group has shown that tasks with Purpose reduce physiologic arousal, consistent with the actions of OT (Kraig et al., 2018). We therefore hypothesized that, along with Trust, an understanding of the organization's Purpose is another physiologic route through which colleagues induce OT release in each other.

Causal Model

Figure 1 presents a schematic model that identifies the causal relationships we will test, associating Trust and Purpose with business outcomes. We will test this model in two ways. First, by measuring the cross-section variation in Trust and Purpose and associating these with performance measures. Second, we will analyze the effect of actively changing Trust to establish causation.

STUDY 1: NATIONAL DATA

The first test of the model uses a nationally representative sample of United States working adults collected in February 2016 by the survey company Qualtrics. It matches United States demographics for age, sex, ethnicity, and geographic dispersion, with 1,095 respondents from all 50 states. The majority of the sample, 79%, consists of people working in the for-profit sector with the remainder working for government and non-profits. The survey was designed to test if a culture of Trust and Purpose affects individual and company performance. This paper will use multiple dependent variables to generate convergent evidence that these aspects of culture drive performance. The Institutional Review Board of Claremont Graduate University approved this study and all participants provided informed consent before inclusion.

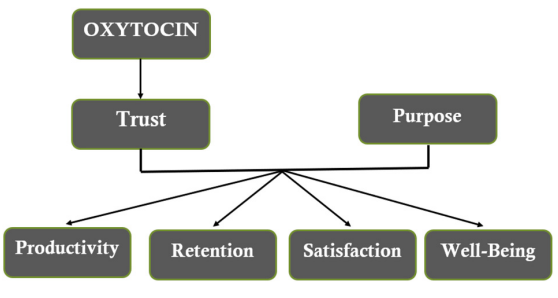

FIGURE 1 | A causal model relating Trust and Purpose to individual and organizational outcomes.

Variables

The national survey collected information about demographics, behaviors and attitudes toward work, and quality of life. To quantify organizational trust, the eight OXYTOCIN factors were assessed and averaged. Purpose is measured as the average of three questions about personal alignment with the organization's values (see **Appendix**).

The dependent variables are productivity, retention, joy at work ("Joy"), job satisfaction, closeness to colleagues, satisfaction with life (SWL), chronic stress, and depersonalization. Productivity is measured in two ways. The first is by self-report, although these data are suspect as the median response is 95 out of 100. To overcome this bias, the second way uses a subset of responses to the Utrecht Work Engagement Scale called "vigor" as a proxy for productivity following previous research (Schaufeli and Bakker, 2004; Schaufeli et al., 2006; De Bruin et al., 2013; White et al., 2014). Vigor assesses how much energy colleagues have during work tasks, how immersed people are in their work, if they feel energized while working, if they can work for long periods of time, and if they are mentally resilient at work. Retention is determined from responses about the likelihood of continuing to work for the organization for the next 12 months. Job satisfaction is ranked on a 7-point scale, closeness to colleagues is measured using the Inclusion of Others in Self survey (IOS; Aron et al., 1992), and well-being was captured using the SWL survey (Diener et al., 1985). Chronic stress was measured on a seven-point scale, while depersonalization is part of the Maslach Burnout Inventory (MBI; Maslach et al., 1996). Depersonalization has been shown to be a significant indicator of chronic stress and burnout (Maslach and Jackson, 1981; Leiter and Maslach, 1999). Joy is measured by averaging two questions from Zak (2017) that ask how much one enjoys working on a typical day. Income is measured in $25,000 intervals.

Control variables include the number of hours worked per week, age, and marital status. We also assessed participants' conscientiousness as a personality trait using the Big Five Inventory (BFI; John and Srivastava, 1999). This trait has been associated with higher levels of productivity, job-satisfaction, and well-being (Dobewall et al., 2013; Berglund et al., 2015; Cubel et al., 2016).

Analytical Approach

Data analysis was performed using t-tests of differences in means, correlations, and least squares regressions. We also estimated ordered-logistic and log-log regressions to determine predictive

accuracy and size effects (elasticities). The data were analyzed in aggregate, as well as broken into categories, such as organization type, and high-trust and low-trust groups in order to present convergent evidence for our hypotheses.

RESULTS: NATIONAL DATA

Descriptive statistics are presented in **Table 1** for the OXYTOCIN components, dependent, independent, and control variables.

OXYTOCIN and Trust

All eight OXYTOCIN factors were highly correlated with trust: (Ovation $r = 0.735$; eXpectation $r = 0.906$; Yield $r = 0.630$; Transfer $r = 0.892$; Openness $r = 0.734$; Caring $r = 0.890$; Invest $r = 0.840$; Natural $r = 0.880$; t-tests, $ps < 0.0000$). Each factor is given equal weight when measuring organizational trust. In this sample, Ovation had the lowest average score and Transfer had the highest. Assessing reliability of the measures using Cronbach's alpha, we find $\alpha = 0.93$.

Productivity and Retention

Productivity and retention directly increase profit and shareholder value and are therefore the first outcomes we analyzed. Trust increased productivity measured both by vigor from the Utrecht engagement scale ($r = 0.55$, $p = 0.000$) and by self-report ($r = 0.51$, $p = 0.000$). Purpose also positively increased both productivity measures (vigor: $r = 0.60$, $p = 0.000$; self-report: $r = 0.50$, $p = 0.000$). Similarly, higher levels of Trust and Purpose increased colleague retention (Trust: $r = 0.57$, $p = 0.000$; Purpose: $r = 0.56$, $p = 0.000$). The partial correlations from Trust and Purpose on these outcome measures are similar when hours worked, personality, age, income, sex, and marital status are included as controls (**Table 2** and **Appendix**).

The size effects of an increase in Trust or Purpose are moderately high. An organization that increased Trust by 10% would see a rise in productivity of 1.57% for vigor and by 4.50% using the self-report data. Similarly, a 10% increase in Purpose would raise productivity between 2.38% (vigor) and 2.72% (self-report). Analyzing the impact of an increase in Trust and Purpose on retention shows that a 10% increase in either would cause a 3.9% increase in retention.

Income

Trust had a positive effect on colleague earnings ($r = 0.10$, $p = 0.0011$). Those in the highest Trust group reported average incomes of 10.3% higher than the middle group ($p = 0.000$) and 11.63% higher than lowest trust group ($p = 0.000$). In competitive labor markets, productivity is closely related to earnings. The higher earnings by colleagues in high Trust organizations indicates that they are more productive than those working on lower Trust companies.

Job Satisfaction, Joy, and Colleague Closeness

Consistent with our hypotheses, Trust increased job satisfaction ($r = 0.59$, $p = 0.000$) and closeness to colleagues ($r = 0.40$,

TABLE 1 | Descriptive statistics for the national sample.

Type	Variable	Mean	SD	Min	Max
Independent	Ovation	3.815	1.252	1	6
Independent	eXpectation	4.278	1.405	1	6
Independent	Yield	3.996	1.173	1	6
Independent	Transfer	4.315	1.379	1	6
Independent	Openness	3.941	1.245	1	6
Independent	Caring	4.133	1.417	1	6
Independent	Invest	4.161	1.377	1	6
Independent	Natural	4.143	1.424	1	6
Independent	Organizational Trust	4.216128	1.135205	1	6
Independent	Purpose	4.3188	1.32118	1	6
Dependent	Productivity (Vigor)	5.170002	1.356382	1	7
Dependent	Productivity	77.32694	24.24813	0	100
Dependent	Retention	4.84275	1.448044	1	6
Dependent	Job Satisfaction	4.59726	1.408836	1	7
Dependent	Closeness to Colleagues	3.234703	1.507047	1	6
Dependent	Joy	4.575576	1.2258	1	6
Dependent	Well-being	15.2188	6.64217	1	28
Dependent	Chronic Stress	2.677479	1.18226	1	6
Dependent	Income	3.374 ($59,249)	1.78564	1 (<$25,000)	8 ($200,000+)
Control	Sex	0.5022831	0.5002233	0	1
Control	Hours worked/week	2.36803 (43.68)	0.84475	1 (<20)	5 (>60)
Control	Age	3.08432 (35–44 years)	1.514434	1 (18–24)	6 (65+)
Control	Married	0.456621	0.4983423	0	1
Control	Personality (conscientiousness)	4.088245	0.6193216	1	5

TABLE 2 | Trust continues to be positively related productivity and retention when control variables are included.

Variables	(1)	(2)	(3)
	Productivity (Vigor)	Productivity (Self-Report)	Retention
Organizational Trust	0.168**	4.036**	0.431**
	(0.0380)	(0.748)	(0.0466)
Purpose at Work	0.335**	3.907**	0.330**
	(0.0321)	(0.632)	(0.0394)
Weekly Hours	0.126**	−0.685	0.0822
	(0.0370)	(0.729)	(0.0445)
Personality	0.676**	10.71**	0.0772
	(0.0551)	(1.084)	(0.0679)
Age	0.0918**	1.427**	0.0778**
	(0.0208)	(0.408)	(0.0250)
Income	0.000358	−0.600	0.0132
	(0.0188)	(0.369)	(0.0228)
Female	−0.122*	0.0398	0.0999
	(0.0614)	(1.207)	(0.0739)
Married	−0.101	1.223	0.0206
	(0.0650)	(1.278)	(0.0784)
Constant	−0.196	−1.083	0.722**
	(0.214)	(4.210)	(0.263)
Observations	1,078	1,078	1,054
R-squared	0.486	0.358	0.384
VIF	1.47	1.47	1.47

*Standard errors in parentheses. **$p < 0.01$, *$p < 0.05$.*

p = 0.000). Purpose also had a positive impact on both job satisfaction (r = 0.57, p = 0.000) and closeness to colleagues (r = 0.36, p = 0.000). The quantitative effect of raising Trust and Purpose are similar when hours worked, personality, age, income, sex, and marital status are included as controls (**Table 3** and **Appendix**). A 10% increase in Trust is associated with a 4.5% increase in job satisfaction and 4% greater closeness to colleagues. The impact of an increase in Purpose is similar: a 10% increase would result in 2.6% more job satisfaction and 1.7% greater closeness to colleagues.

The neuroscience predicts a nonobvious aspect of high-Trust and high-Purpose cultures: people will enjoy working at them. Both Trust and Purpose are highly correlated with Joy (Trust: r = 0.78, p = 0.000; Purpose: r = 0.75, p = 0.000). The science also predicts that Trust and Purpose reinforce each other at work and the data support this with a high correlation between Trust × Purpose and Joy (r = 0.80, p = 0.000). If a company were able to increase Trust by 10%, this would raise Joy by 5% (p = 0.000). Similarly, a 10% increase in Purpose would positively impact Joy by 3.1% (p = 0.000). If organizations instituted programs to increase both Trust and Purpose by 10%, Joy would rise by 7.8% (p = 0.000).

Chronic Stress and Satisfaction With Life

Chronic stress and SWL are primary indicators linked to well-being (Binder and Ward, 2013; Berglund et al., 2015; Kjell et al., 2016). Chronic stress drives job turnover and inhibits one's SWL outside of work. We tested the effect of Trust and Purpose on job burnout and depersonalization using the Maslach Burnout Inventory. We found that Trust reduced chronic stress (r = -0.42, p = 0.000) and depersonalization (r = -0.37, p = 0.000) and Purpose had similar effects (stress: r = -0.32, p = 0.000; depersonalization: r = -0.35, p = 0.000). As expected, both factors had positive effects on SWL (Trust: r = 0.36, p = 0.000; Purpose: r = 0.39, p = 0.000). These results continue to be significant and are of similar magnitude when control variables are included (**Table 4** and **Appendix**).

Assessing elasticities, an increase in Trust by 10% would reduce chronic stress by 4.7%, decrease depersonalization by 3.3%, and increases SWL by 1.5%. A 10% increase in Purpose would have similar effects, reducing chronic stress by 0.10%, diminishing depersonalization by 1.7%, and increasing SWL by 2.4%.

Non-profits

People working for non-profit organizations had the same Trust but higher Purpose compared to colleagues in for-profit businesses. Purpose was 10.2% higher (p = 0.001) compared to private industry. This produced greater job satisfaction for those working in nonprofits, 6.2% higher than employees in businesses (p = 0.039). At the same time, organizations in the social sector have 3.56% (p = 0.066) lower productivity than for-profit businesses and consequentially the average nonprofit employee earns 8.6% less (p = 0.089) than employees in businesses.

TABLE 3 | Trust and Purpose have a positive relationship on job satisfaction and colleague closeness when controls are included.

Variables	(4)	(5)
	Job Satisfaction	Closeness with Colleagues
Organizational Trust	0.439**	0.348**
	(0.0431)	(0.0545)
Purpose at Work	0.295**	0.135**
	(0.0364)	(0.0461)
Weekly Hours	0.0391	−0.0512
	(0.0420)	(0.0531)
Personality	0.0714	0.246**
	(0.0624)	(0.0791)
Age	0.0494*	−0.0417
	(0.0235)	(0.0298)
Income	−0.0564	0.169
	(0.0736)	(0.0932)
Female	0.0417	−0.278**
	(0.0695)	(0.0880)
Married	0.0893**	0.0331
	(0.0212)	(0.0269)
Constant	0.654**	0.386
	(0.242)	(0.307)
Observations	1,078	1,078
R-squared	0.406	0.188
VIF	1.47	1.47

*Standard errors in parentheses. **$p < 0.01$, *$p < 0.05$.*

DISCUSSION: NATIONAL DATA

Our findings have demonstrated that organizations with cultures that empower colleagues with Trust and Purpose perform significantly better than their peers. This improved performance is due to greater colleague productivity, lower turnover, and higher satisfaction at work and at home. Traditional economic theory pits the interests of organizations and employees against each other, where firms must continually tweak incentive schemes and constantly monitor employees to ensure effort at work (Fehr and Gachter, 2000; James et al., 2011; Spencer, 2015). Counter to this perspective is the labor market gift exchange model developed by Akerlof (1982) in which work colleagues respond to the gift of wages offered by the firm by providing discretionary effort to their employers (Mahmood and Zaman, 2010; Akerlof, 1982; Fehr and Gachter, 2000). Our analysis shows that Trust may also be viewed by work colleagues as a gift, generating higher productivity and longer job tenure. This is corroborated by our finding that high-trust organizations reciprocate additional effort by paying colleagues a premium over wages at lower-trust companies. Organizations in the highest quintile of Trust pay employees 10.3% more than employees working in companies in the middle quintile of Trust and 11.6% more than the quintile of the lowest Trust companies ($ps < 0.05$). Demographics were not significantly different between the Trust quintiles, with age, sex, and race being similarly distributed in each (**Appendix**). The United States labor market is highly competitive so higher wages indicate that high-trust companies are more profitable than low-trust ones. This is confirmed in findings for productivity. Colleagues working in the highest Trust organizations report productivity that is more than 250% ($p = 0.000$) higher than the lowest Trust quintile and 50% ($p = 0.000$) more than the middle quintile.

The productivity difference in high-trust organizations indicates that colleagues are exerting discretionary effort. Joy at work often comes when people make progress on projects (Amabile and Kramer, 2011) and the greater productivity of high-Trust organizations also produces Joy. Colleagues working in companies in the highest quartile of Trust had 21.7% more Joy than the middle quartile and 89.7% more Joy than the lowest Trust quartile. These effects suggest that company culture promotes effective teamwork.

Job satisfaction is another measure of the intrinsic and extrinsic value people receive from work (Mirvis and Hackett, 1983; White et al., 2014). Satisfaction at work has positive effects on both productivity ($r = 0.55$, $p = 0.000$) and turnover ($r = -0.44$, $p = 0.000$) as others have shown (Ertürk and Vurgun, 2015; Frederiksen, 2016), creating value for organizations. Job satisfaction for respondents working in the top Trust quintile was 42% ($p = 0.000$) higher than those working in bottom group and 17% ($p = 0.000$) higher compared to those in the middle quintile. Our analysis also showed that non-profit colleagues have 6.2% ($p = 0.001$) higher job satisfaction than those working in private sector. This confirms other research showing that working for a nonprofit organization produces higher job satisfaction compared to employees in for-profit companies (Mirvis and Hackett, 1983). We traced this effect to a greater understanding of the organization's Purpose than was found among for-profit employees. More generally, job satisfaction can be increased in for-profits and non-profits by raising Trust or Purpose. For example, those working in the highest Trust private sector quartile had 16.4% ($p = 0.000$) more job satisfaction than the average for non-profit colleagues.

Employee retention is critical for firm performance due to the high costs associated with recruiting, on-boarding, and training new employees, as well as the value of firm-specific knowledge that accumulates on the job (Meister, 2012; Bersin, 2014; Mason and Bishop, 2015). Recruiting and on-boarding averages nearly one year annual salary for professional positions (Tracey and Hinkin, 2008; Merhar, 2016). The analytics herein show that Trust has a significant impact on the intention of colleagues to remain with their current employer. Fully 95% of respondents in the highest Trust quintile planned to stay with their employer for the next year ($p = 0.000$). This significantly reduces costs for these employers. Conversely, in the lowest Trust quintile, 51% ($p = 0.000$) planned to leave employment in the next year. Accordingly, respondents in the highest Trust quintile have 28 months longer job tenure than the lowest quintile ($p = 0.000$). In addition to more productive colleagues at high-Trust organizations, greater retention also gives them a competitive edge.

We also found that organizational trust had a positive effect on employees' lives outside of work. Those working in highest Trust quintile had 16.2% ($p = 0.000$) greater life satisfaction than the middle quintile and 54.5% ($p = 0.000$) more life satisfaction

TABLE 4 | Trust and Purpose continue to be positively associated with well-being and Joy and are mostly negatively associated with stress and depersonalization when controls are included.

Variables	(6)	(7)	(8)	(9)
	Well-Being	Joy	Chronic Stress	Depersonalization
Organizational Trust	0.636**	0.509**	−0.380**	−1.630**
	(0.224)	(0.0275)	(0.0422)	(0.349)
Purpose at Work	0.898**	0.331**	−0.00547	−0.910**
	(0.190)	(0.0232)	(0.0353)	(0.295)
Weekly Hours	0.0624	0.0470	0.200**	1.108**
	(0.219)	(0.0266)	(0.0404)	(0.340)
Personality	2.176**	0.180**	−0.233**	−2.648**
	(0.325)	(0.0398)	(0.0604)	(0.505)
Age	−0.379**	0.0336*	−0.120**	−1.286**
	(0.122)	(0.0149)	(0.0227)	(0.190)
Income	0.628**	−0.0122	0.0169	−0.0440
	(0.111)	(0.0135)	(0.0205)	(0.172)
Female	0.110	0.110*	−0.111	−0.587
	(0.362)	(0.0440)	(0.0671)	(0.563)
Married	2.530**	0.0289	−0.0331	−0.355
	(0.383)	(0.0466	(0.0711)	(0.596)
Constant	−2.500*	0.0279	5.172**	41.47**
	(1.263)	(0.154)	(0.235)	(1.963)
Observations	1,078	1,073	1,065	1,078
R-squared	0.286	0.687	0.240	0.222
VIF	1.47	1.48	1.47	1.47

*Robust standard errors in parentheses. **$p < 0.01$, *$p < 0.05$.*

than the lowest group. One way Trust improves life satisfaction is by reducing chronic stress. Colleagues who moved from the lowest Trust quintile to the middle quintile would face 15.8% less chronic stress ($p = 0.000$); moving from the middle to the highest Trust quintile would reduce chronic stress by 34.5% ($p = 0.000$). Not only did Trust reduce chronic stress, it was associated with overall improvements in health. Our analysis shows that colleagues with jobs in the highest Trust quintile took 8.5 ($p = 0.047$) fewer sick days compared to the middle Trust quintile. Overall health for those in the highest quintile of Trust was 13% better than those in the middle quintile ($p = 0.000$) and 17% better overall than the lowest group ($p = 0.000$). These findings taken as a whole suggest that Trust helps to align the incentives of organizations and employees.

Our analysis showed that Purpose also affects the performance of organizations. This starts with a clear Purpose statement and processes that keep Purpose top of mind for colleagues. This can be done by stating the organization's Purpose at the beginning of meetings, and displaying it on posters, screensavers, or apps. For example, the management consulting firm KPMG built an app called "10,000 stories" so colleagues could share the positive ways they have improved their clients' lives (Pfau, 2015). They expected it could take years to collect 10,000 stories; they reached this goal in 2 months. Within a year, 42,000 stories had been collected. The annual KPMG partner survey completed after the 10,000 stories app launch showed that 90% of respondents reported this Purpose initiative increased their pride in working for KPMG.

Purpose directly improves job satisfaction, productivity, Joy, retention and well-being ($r = 0.57$, $p = 0.000$; $r = 0.57$ $p = 0.000$; $r = 0.75$, $p = 0.000$; $r = 0.56$, $p = 0.000$; $r = 0.37$, $p = 0.000$). For example, those working in highest quintile of Purpose organizations are 66.4% more satisfied with work than the lowest quintile ($p = 0.000$) and 22.6% more satisfied than the middle quintile ($p = 0.000$). Similarly, people working in the highest Purpose organizations experience 20.2% more Joy than those in the middle quintile ($p = 0.000$) and 81.6% more Joy than employees in the lowest quintile ($p = 0.000$). High Purpose also increases outside-of-work life satisfaction. SWL is 15.2% higher for employees in the highest Purpose quintile compared to the middle ($p = 0.000$) and 39.6% higher than those working in the bottom quintile ($p = 0.000$).

The national data show that building Trust and Purpose into organizational cultures effectively improves individual and economic outcomes. Once Trust and Purpose become foci to improve organizational performance, the measures used in this study can be applied to systematically influence the Trust by intervening to raise one or more of the OXYTOCIN factors. Study 2 analyzes a business that did this to assess its effects on performance.

STUDY 2: TRUST INTERVENTION AT AN ONLINE RETAILER

Study 1 demonstrated the effect of Trust and Purpose on multiple measures of organizational performance by analyzing a cross-section of working adults. Study 2 examines the effect of a Trust intervention in one division of a large online retailer. The

longitudinal approach of Study 2 is designed test the causal impact of Trust on business-relevant outcomes.

The leaders of a large (revenue > $1 billion) online retailer (OnRet) identified low morale and high job turnover as key performance indicators they sought to affect in a division of their company. The company is very well run and even the division for which we created an intervention performs well on most metrics (**Table 5**). OnRet supported the intervention by inviting our team to their headquarters and having their executives participate in the kick-off meeting with 66 colleagues from the division. Data were collected prior to the intervention to measure the OXYTOCIN factors and provide baseline values for outcomes (N = 59). Because the OXYTOCIN factors all face ceiling effects, intervening to raise the lowest factor is expected to have a larger impact on Trust and performance than influencing a factor that is already high. The baseline data showed that the lowest factor was Natural and a 3-month intervention, described below, was designed and executed to increase Natural. After the intervention concluded, the survey was repeated to assess the OXYTOCIN factors, Trust, Purpose, and job retention. Not all variables in Study 1 could be measured in this study because OnRet's leadership was concerned about the time colleagues would spend responding to survey questions.

Intervention

Trust, as measured by the OXYTOCIN factors, is a set of behaviors. The intervention sought to change one of these behaviors, Natural, the ability to be one's authentic self at work. It takes 90 days or longer of deliberate practice to change habitual behaviors and practice of the new behavior needs to be done consistently (Fogg, 2011; Dean, 2013). An effective way to create new habits is through microlearning techniques (Jaokar, 2007). These are short, intense, practice-based messages that "nudge" learners toward new behaviors.

We created 10 microlearning videos with the help of Envisia Learning (Santa Monica, CA, United States) that one of the authors wrote and narrated (PJZ). These were animated whiteboard videos that discussed the science of authenticity and asked viewers to do one new thing immediately. We also crafted 10 email reminders focusing on being Natural at work that asked employees to rate a particular aspect of Natural on a 1–7 scale. These pulse questions were designed to reinforce the new behavior. OnRet agreed to let us send their colleagues one microlearning video for 10 consecutive work days. After that,

TABLE 5 | Descriptive statistics for the field experiment before and after Trust-building intervention.

Type	Variable	Survey 1 Mean	SD	Survey 2 Mean	SD
Independent	Ovation	3.372881	0.4964809	3.442308	0.3828034
Independent	eXpectation	4.084746	1.130123	4.365385	1.323312
Independent	Yield	3.194915	0.7370547	3.423077	0.5777942
Independent	Transfer	4.144068	1.110494	4.326923	1.462479
Independent	Openness	3.271186	0.6905897	3.461538	0.5276946
Independent	Caring	4.271186	1.134574	4.043846	1.385779
Independent	Invest	4.059322	1.286819	4.192308	1.435806
Independent	Natural	3.59322	1.112137	4.153846	1.222859
Independent	Trust	62.48234	10.77594	66.1859	13.72545
Independent	Purpose	4.559322	1.040264	4.782051	1.173569
Dependent	Retention	5.372881	1.01537	5.423077	1.238485
Control	Sex	0.5932203	0.4954498	0.4615385	0.5083911

TABLE 6 | Natural and Trust are more strongly related to retention after the intervention while Purpose loses its significance.

Variables	Retention (January)	Retention (June)	Retention (January)	Retention (June)
Natural	0.0887	0.367*		
	(0.123)	(0.164)		
Trust			0.0258	0.0433*
			(0.0141)	(0.0168)
Purpose	0.396**	0.490**	0.272	0.312
	(0.131)	(0.171)	(0.146)	(0.196)
Constant	3.247**	1.552	2.524**	1.070
	(0.564)	(0.905)	(0.700)	(0.954)
Observations	59	26	59	26
R-squared	0.212	0.454	0.249	0.485
VIF	1.29	1.11	1.68	1.54

*Standard errors in parentheses. **$p < 0.01$, *$p < 0.05$.*

team members of this division received an email pulse question every Monday for the next 10 weeks. After a 2-month washout period to establish the stability of the changes, a survey was again sent to colleagues to assess Natural, the other OXYTOCIN factors, Trust, Purpose, and one outcome measure, job retention (N = 26). Due to department restructuring, not all colleagues who received the microlearning videos and email reminders completed the post-intervention survey.

Analytical Approach

Data was analyzed through paired t-tests, correlations, and ordinary linear regressions. Additional results were obtained using ordered-logistic and log-log regressions.

RESULTS: TRUST INTERVENTION

Table 5 shows the values for the baseline and post-intervention measures and their standard deviations.

The data show that the intervention was successful at raising Natural. Only 62.7% of respondents has a positive view of Natural before the intervention compared 80.7% after (p = 0.041). The average value of Natural increased 15.6% (p = 0.02, one-tailed t-test) after 5 months (3 month intervention and 2 month wash-out). The change in Natural produced an increase in those rating Trust as favorable from 81.4 to 84.6% (p = 0.038, one-tailed t-test) although the average level of Trust was not statistically significant different likely due to the small sample size (change: 5.9%; p = 0.075; one-tailed t-test). The intervention also strengthened the correlations between Natural and Trust (r_1 = 0.7974, r_2 = 0.8846 p = 0.000).

The analysis also found that the intervention increased the correlations of job retention with Natural and Trust (Natural: r_1 = 0.289, r_2 = 0.501; Trust: r_1 = 0.450, r_2 = 0.655; ps $<$ 0.03). As a result, we estimated a linear regression to assess the impact of Natural and Trust on job retention. We found that pre-intervention, Natural was unrelated to job retention, while Trust had a positive and significant relationship with retention. After the intervention, both Natural and Trust were both independently associated with greater job retention (ps $<$ 0.05; **Table 6** and **Appendix**).

DISCUSSION: TRUST INTERVENTION

Study 2 sought to determine the causal effect of changing one of the OXYTOCIN factors on Trust, Purpose, and performance. The intervention increased favorable views of Natural by 28.7%. Using the values from the National sample, only a 2% change in Trust would have been expected due to the intervention, yet we found a nearly 6% increase in Trust. This was the result of the intervention increasing the average value of seven of the eight OXYTOCIN factors, though all failed to reach statistical significance. Trust begets Trust, and the increase in Natural appeared to have primed colleagues to change other trust-building behaviors.

Sample attrition is a common in field studies and the intervention faced substantial attrition. This makes it difficult to draw conclusions with confidence other than that a 3 month intervention can change one of the OXYTOCIN factors over a 5-month period. Nevertheless, the trends seen in Trust and the other OXYTOCIN factors were in the right direction and were quantitatively meaningful based on the impact on performance measures in Study 1. Trust at OnRet fell into the middle quintile of the national survey, with retention rates similar to the fourth quintile. Extrapolating from the results from Study 1, higher levels of Trust due to the intervention would have increased job satisfaction by 2.7%, life satisfaction by 1%, productivity by 1% and reduced chronic stress by 2.8%.

The design of behavioral "nudges" is consistent with the learning literature and produced the desired effect. The approach used here should be replicated in larger samples in order to fully evaluate its use in businesses. More generally, our findings on Trust and Purpose show that they can be consistently measured and managed to improve performance.

CONCLUSION

The two studies in this paper show that organizational Trust and Purpose provide substantial leverage to improve business-relevant outcomes. The evidence showed that both Trust and Purpose increase productivity and earnings by employees, reduce job turnover, improve job satisfaction, and make people happier and healthier, aligning the incentives of firms and employees. We propose that companies that ignore the human element at work, falling into the trap of treating employees like capital rather than people, will become performance laggards compared to organizations that empower their workforces with Trust and Purpose.

Business is highly competitive and finding new dimensions to improve performance is an important way to sustain profits. While the effects of culture on business performance have been established, which aspects of culture matter the most is still an open issue. The studies here have identified two aspects of culture that managers can measure and manage to improve performance.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

PZ conceived and designed the survey and field experiment and collected data from field study. Both authors collected data from survey, analyzed the data, and wrote the manuscript.

ACKNOWLEDGMENTS

We thank the Fraser Institute for funding the data collection in Study 1 and Evisia Learning for the video preparation for Study 2.

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

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APPENDIX

Organizational Trust and Purpose Questionnaire

Scoring: 1 = Strongly Disagree 2 = Disagree 3 = Somewhat Disagree 4 = Somewhat Agree 5 = Agree 6 = Strongly Agree 0 = Not observable/Not Applicable

1: Overall, I believe this organization is an excellent place to work.
2: My leader treats setbacks and mistakes I make as a valuable opportunity to learn and try something new.
3: My leader does not notice and demonstrate appreciation for my progress and the effort it takes to get things done well.
4: My leader takes time to listen and understand my point of view.
5: My leader can be relied upon to do the right thing even when it's challenging or difficult.
6: I have enough time to perform and complete all the tasks required on my job.
7: I would recommend working for this organization to a relative or friend.
8: My leader expresses confidence in me or provide the necessary tools and resources to be successful on the job.
9: My leader shares timely information and knowledge freely and openly.
10: I have opportunity to develop additional skills and experiences at work.
11: My workload interferes with my personal or family time (i.e., does not allow me adequately detach and recover).
12: I am likely to stay with this organization for the next 12 months.
13: I enjoy my job.
14: I feel I am doing something worthwhile.
15: My leader does not encourage me to openly share my thoughts, suggestions and ideas.
16: My leader helps me understand how I can use my talents to professionally grow and develop further.
17: My leader meaningfully recognizes my efforts and achievements in a timely and appropriate manner.
18: My leader encourages me to do my best.
19: My leader does not provide autonomy, flexibility and control in deciding how I can make decisions and do my work.
20: My leader knows what matters to me and how best to support me.
21: My leader collectively agrees upon clear and challenging performance goals with me.
22: My leader utilizes and capitalizes on the full range of my skills, expertise, and experiences.
23: My leader is someone who confidently shares both their strengths and vulnerabilities openly and honestly.
24: I feel my work has a positive impact on the world.
25: I appreciate the values for which my organization stands.
26: Overall, I enjoy the people I work with.

SCORING_KEY = { a "−" indicates reverse scoring}

"Ovation" → [−3, 17], "eXpectation" → [18, 21], "Yield" → [2, −19], Transfer → [8, 22], Openness → [−15, 9], Caring → [4, 20], Invest → [10, 16], Natural → [5, 23], Joy → [26, 13], Purpose → [25, 24, 14], Stress → [6, −11], Engagement → [12, 1, 7].

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MINI REVIEW
published: 16 March 2021
doi: 10.3389/fpsyg.2021.602843

A Literature Review of EEG-Based Affective Computing in Marketing

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Affect plays an important role in the consumer decision-making process and there is growing interest in the development of new technologies and computational approaches that can interpret and recognize the affects of consumers, with benefits for marketing described in relation to both academia and industry. From an interdisciplinary perspective, this paper aims to review past studies focused on electroencephalography (EEG)-based affective computing (AC) in marketing, which provides a promising avenue for studying the mechanisms underlying affective states and developing recognition computational models to predict the psychological responses of customers. This review offers an introduction to EEG technology and an overview of EEG-based AC; provides a snapshot of the current state of the literature. It briefly presents the themes, challenges, and trends in studies of affect evaluation, recognition, and classification; and further proposes potential guidelines for researchers and marketers.

Keywords: electroencephalography, affective computing, marketing, neural affective mechanisms, classification and recognition

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Edited by:
Tao Liu,
Zhejiang University, China

Reviewed by:
Dan Zhang,
Tsinghua University, China
Xiaoli Tang,
Yanshan University, China

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *04 September 2020*
Accepted: *19 February 2021*
Published: *16 March 2021*

Citation:
Pei G and Li T (2021) A Literature Review of EEG-Based Affective Computing in Marketing. Front. Psychol. 12:602843. doi: 10.3389/fpsyg.2021.602843

INTRODUCTION

Affective computing (AC) is a continuously growing interdisciplinary research field spanning psychology, computer science, cognitive science, neuroscience, and more (Tao and Tan, 2005). In Picard's landmark book, AC is defined as "computing that relates to, arises from, or deliberately influences emotion or other affective phenomena" (Picard, 1997). It mainly focuses on how technology can inform and deepen understanding of human affect and how systems can be designed to estimate the affective state using computational models from behavioral and physiological signals (Calvo and D'Mello, 2010).

Affect plays an important role in human cognition, specifically in perception processes, rational decision-making, human communication, and human intelligence (Ammar et al., 2010; Singh et al., 2013). In marketing, understanding and recognizing the affective states of users (or customers) has become a vital theme, which can reveal users' true preferences and improve and assist in the purchasing process (Malär et al., 2011; Garrido-Morgado et al., 2015).

Conventional assessment methods of AC in marketing depend mostly on personal evaluations, such as surveys, focus groups, and interviews (Ariely and Berns, 2010; Yadava et al., 2017; Lin et al., 2018). However, customers may not express their true opinions because of social desirability bias (Paulhus, 2002; Vecchiato et al., 2011a). They may not say exactly how they are feeling but rather, how they feel others would reply (Calvert and Brammer, 2012). These *post hoc* analysis tools are also influenced by individuals' mental states or environments at the time of self-reporting (Nilashi et al., 2020). Due to the limitations of traditional AC techniques, marketers and researchers try to supplement these shortcomings and seek alternative or complementary tools. Neuroscientific tools

based on electrophysiological and neuroimaging techniques provide one such alternative, as well as a way to dig deeper into understanding the complex evaluation process and the dynamics of the affective state by directly accessing the physiological signals and fundamental cerebral structure from which an affective state occurs.

Considering its low cost and high temporal resolution (milliseconds), electroencephalography (EEG) has become common and is extensively used in the marketing industry. Furthermore, variations in EEG signals cannot be voluntarily controlled and therefore are a better objective indicator of affect (Singh et al., 2013). EEG-based AC provides a promising avenue for studying the mechanisms underlying affective states and developing recognition computational models to predict the psychological responses of customers. It can, therefore, be widely used to boost sales, advertising, pricing, package design, marketing campaigns, and so forth (Calvo and D'Mello, 2010).

In this review, we focus on EEG-based AC in marketing. First, we stress the need to incorporate the various features of neural signals that contribute to consumers' affective states and evaluation processes beyond what traditional marketing measures already provide. Second, we state that marketing studies should adopt the methodologies and algorithms used in data processing and prediction modeling that are mature in other fields such as computer science and engineering. We examine AC literature in marketing on the general features extracted from EEG recordings and conclude with a general discussion of the challenges faced by this field, providing several recommended guidelines for the road ahead.

CONSUMERS' NEURAL AFFECTIVE MECHANISMS

It is expected that a deeper understanding of how the human brain works and responds will make marketing more effective (Kuan et al., 2014; Nagyová et al., 2014; Caratù et al., 2018). Researchers and marketers have attempted to reveal the neural correlates and neural affective mechanisms that affect decision making in customers and consumer behavior in economic processes.

Event-Related Potentials

As an extremely useful tool for investigating higher-level brain functions, event-related potentials (ERPs) have been widely used to explore the neural mechanisms underlying affect processing in marketing. For example, Ma et al. (2007) found that brand extension preferences were modulated by negative emotions. These underlying mechanisms were indicated by the amplitudes of N270. This research presents a method, which is automatic, objective, and non-verbal, for the use of ERP components as markers for emotional preferences. Jones et al. (2012) shifted their attention toward pricing and discount-related consumer behavior. The enhanced P3 in high math anxiety individuals indicated greater reliance on the emotional and motivational factors involved in the buying process. Social interaction in marketing is another important theme. In a study by Pozharliev et al. (2015), the late positive potential (LPP) was enlarged during shopping for luxury products. It was especially prominent in the presence of another person during buying decisions, suggesting that social interaction magnifies the emotional effect of the brand category. Furthermore, Chen et al. (2010) found that N500 was evoked by emotional conflicts when making counter conformity choices in buying books online.

By taking full advantage of the high temporal resolution of ERPs, a group of scientists conducted multistage experiments and multicomponent detections to decompose the time course of neural cognitive and affective activities. Handy et al. (2010) focused on the emotional appraisal of unfamiliar commercial logos. Using an ERP examination, they found that the judgment of logos can be divided into at least two stages: an initial formation of ones' impression at the sensory-perceptual level and evaluative analysis at the cognitive-processing level. Jin et al. (2018) demonstrated that eco-labeling induced positive emotions in consumers and reduced cognitive conflict, as reflected by decreased P2 and N2 amplitudes, respectively. In another study, Shang et al. (2020) studied online shopping and focused on the influence of webpage layouts on consumer experience. They demonstrated that a low-order online shopping webpage facilitated consumers' instant purchase decisions as indexed by increased P2 (attention engagement) and LPP (emotional self-control) amplitudes. Separating affective activities from cognitive activities and capturing independent processes within each stage is helpful to provide a deeper and more nuanced understanding of consumers' neural affective mechanisms.

EEG Time-Frequency Components

Because EEG signals comprise abundant time-frequency information, multiple characteristic parameters, such as hemispheric asymmetry, event-related desynchronization/synchronization (ERD/ERS), and power spectral density (PSD), are closely related to affective states.

Concerned with the frontal EEG asymmetry, Vecchiato et al. (2010) revealed that the cerebral activity of the theta band on the left frontal hemisphere increased when television commercials were judged to be pleasant. As a follow-up to this, Vecchiato et al. (2014) further highlighted that the index of cortical hemispheric asymmetry, which was also a valid predictor of preferences, was significantly correlated with participants' pleasantness ratings. Furthermore, the frontal alpha band, as reflected in cerebral hemispheric alpha asymmetry, has been widely used to represent affective responses to advertisements (Ohme et al., 2010; Venkatraman et al., 2015). When two subjects were viewing two versions of the almost same skincare product advertisement (differing only by the inclusion of a very short clip concerning a gesture by a female model), Ohme et al. (2009) found out that each version elicited significantly different emotional impacts, indexed by differences in the frontal alpha activity between the left and the right hemispheres. Similarly, Reeves et al. (1989) reported a significant interaction between hemisphere activity and the emotional content (positive and negative) of television advertisements for frontal alpha power but no interaction for occipital alpha power. It would be more beneficial for future research to specify the role of mediation

and moderation that frontal alpha asymmetry plays in relation to advertisements and affective states (Palmiero and Piccardi, 2017; Allen et al., 2018).

With regard to the ERD/ERS indices, Vecchiato et al. (2011b) demonstrated that desynchronization of the left alpha band is positively related to judgments of high pleasantness. Other findings also supported the evidence that synchronization and desynchronization changes were the result of affective arousal and valence (Aftanas et al., 2001; Costa et al., 2006). Moreover, ERD/ERS is a useful tool for understanding variation in oscillatory activity occurring during the decision-making process related to subjective preferences. Khushaba et al. (2013) explored brain activity while subjects were choosing crackers using EEG and eye tracking data. They found clear phase synchronization between the left and right frontal and occipital regions during preference decision making for the different cracker characteristics, which can be used to predict consumers' future choices and develop effective marketing strategies.

By performing power spectra and PSD analyses, Horska et al. (2016) and Berčík et al. (2016a) studied the emotions of consumers tasting different kinds of wine and used their findings to improve the practical selling strategies. Subsequently, Berčík et al. (2016b) conducted interdisciplinary research on the impact of illumination on the emotional state (valence) of customers in a food store by calculating and comparing alpha and beta spectral power. Lee (2016) explored the emotional mechanism of empathy indexed by the theta-band power spectra of the anterior cingulate cortex (ACC) for customer equity and willingness to pay. Moreover, Vecchiato et al. (2011b) showed that an increase in PSD in the left frontal lobe is negatively related to the degree of perceived pleasantness. These studies indicate that power spectra and PSD are reliable indicators in identifying emotional responses to marketing.

Taken together, the studies discussed above provide evidence that it is helpful to use EEG features and properties to understand neural affective mechanisms, which enables us to objectively reveal hidden consumer reactions and identify critical success factors in the process of buying and consuming certain products (Kuan et al., 2014; Telpaz et al., 2015). We believe that brain wave-based methodologies would further enrich marketing research and help marketers to go beyond traditional marketing paradigms.

CLASSIFICATION AND RECOGNITION OF AFFECTIVE STATES

Feature extraction is a critical step for obtaining an accurate classification result. It is beneficial for simplifying the models and the amount of resources, reducing the cost of data processing, improving data visualization, and avoiding overfitting (Übeyli, 2008; Al-Fahoum et al., 2014). Various methods have been used to extract the neural features from EEG signals. Among these methods are time frequency distributions (appropriate for great continuous segments), fast Fourier transform (suitable for narrowband signal and stationary signal), wavelet transform (good tool for sudden and transient signal changes), auto regressive methods (which are advantageous for short data segments), and so on (Tao and Tan, 2005; Singh et al., 2013; Al-Fahoum et al., 2014; Yadava et al., 2017). Researchers should make clear the signal types and apply the optimum method.

Once the features are extracted, the features will be fed into an affect classification algorithm. Many types of classifiers are commonly used including: support vector machines (SVMs), relevance vector machines (RVMs), logistic model trees (LMTs), Fisher linear discriminant analysis (FLDA), the k-nearest neighbors (KNN), hidden Markov models (HMMs), artificial neural networks (ANNs), artificial bee colonies (ABCs), random forests (RFs), and deep neural networks (DNNs). In the following paragraphs, we present the various types of affective classifiers used in marketing scenarios.

Many studies have used machine learning algorithms to assess the impact of advertising. Friedman et al. (2015) proposed an EEG data-driven approach to measure customers' emotional valence when processing commercials. Their results indicated that hemispheric asymmetry was a good marker and the LMT algorithm (81.2%) provided better classification rates than the SVM algorithm (77.3%). Wei et al. (2018) explored a new method using low-cost EEG headbands to assess the influence of advertisements on purchasing. The EEG features that were closely related to emotions were gathered into different groups and the SVM method was applied to assess the ability of features to predict possible purchases, achieving an accuracy of 77.3%. Yang et al. (2015) developed an approach to evaluate the temporal patterns of EEG data (PSD) and extract affective indices such as happiness and surprise for TV commercial evaluation. FLDA was used to predict which parts of an advertisement could elicit positive emotional responses in customers. Similarly, Guixeres et al. (2017) attempted to forecast the effectiveness of advertisements during the Super Bowl sports event in the United States, based on EEG signals, including biometric responses such as the z-score of the global field power (GFP), hemispheric asymmetry (pleasantness index), and the relative number of peaks in the beta and theta bands (interest index). The results showed that the ANN was able to precisely classify and estimate the effect of each advertisement on the Internet *via* biometrics (82.9% of average accuracy). Marketers could consider the proposed approach at the technical design stages of advertising content. From a multimodal perspective, Gauba et al. (2017) developed a notable rating forecast framework for advertisement clips by using both EEG signals and sentiment analysis of online users' comments from YouTube. The prediction was carried out using the RF regression and was later fused with the sentiment score to improve the overall prediction.

Some scholars pay special attention to the music or jingles of advertisements. Lin et al. (2014) focused on the emotion classification problem when listening to music and used the SVM classifier, generating accuracies of 82.5 and 79.1% for valence and arousal classification, respectively. Gupta and Falk (2016) used EEG graph-theoretic features to classify emotional states while watching music clips with the aid of two classifiers, the SVM and RVM, and the approach achieved a significant improvement in the classification accuracy (The percentage

increase in classification performance ranged from 3 to 9%). More recently, Avinash et al. (2018) developed a very accurate tool for understanding consumers' emotional responses to advertisement jingles. The KNN algorithm was used to classify positive and negative emotions based on theta power signals, achieving an accuracy of 100%.

Other studies have investigated consumers' purchasing preferences. Chew et al. (2016) studied the aesthetic emotional responses in industrial design and buying decisions using EEG signals for virtual 3D shapes with motion. A classification accuracy of up to 80% was attained using the KNN with the alpha, theta, and delta rhythms as the features taken from frontal electrodes to classify two classes, like and dislike. Lobato and Garza (2017) developed a classification algorithm using neural networks and EEG signals to measure the affective states of "do like" and "don't like" during buying processes. Yadava et al. (2017) proposed a predictive model using the HMM classifier to analyze EEG signals to understand consumers' affective states and purchase preferences toward e-commerce goods, and the model achieved an accuracy of 70.33%. They also tested numerous other models, such as the SVM, RF, and KNN. Interestingly, Kumar et al. (2019) creatively put forward a multimodal rating prediction method by fusing the affective ratings from e-commerce websites and EEG data. The ABC and RF models were applied to optimize and compute the ratings from varied data sources, and the results showed that the combined method could achieve a lower Root Mean Square Error (RMSE) in rating prediction compared to a unimodal method. More recently, Aldayel et al. (2020) adopted a deep learning approach to assess consumer preferences (pleasant or unpleasant) by extracting the PSD and valence features. They built four different classifiers, namely, the DNN, RF, SVM, and KNN, which attained accuracies of 94, 92, 62, and 88%, respectively.

In summary, due to significant differences between the experimental design and the paradigm used in these studies, it is difficult to make direct comparisons of the classification accuracies achieved. Furthermore, it seems that there is no particular feature extractor or affective classifier that appears to be the single best choice for all marketing scenarios. In most situations, one should consider as many algorithms as possible from the studies mentioned above and then compare the results with a range of features and algorithms before choosing the one with the best performance for the given marketing application.

DISCUSSION

In this review, we summarize previous studies analyzing EEG signals as biological markers in affective mechanism and recognition in the marketing area (as shown in **Table 1**). The majority of the studies, especially those using machine learning techniques and algorithms, have been published in the last 10 years. This review provides new directions regarding neuromarketing data analyses and fosters cooperation among scholars from miscellaneous disciplines, such as information science, neuroscience, marketing, and psychology. Although there has been a recent increase in the number of EEG-based AC studies in marketing with no signs of slowing down, theoretical and operational challenges must be settled before moving forward.

First, it would be helpful to pay more attention to multiclass affective classification. As this review shows, most of the previous studies are based on dimensional emotion theory, typically concerning the dimensions of arousal, valence, liking, and dominance. The state of the art usually relies on the affective polarity of its components (e.g., positive or negative) and proposes approaches that mostly focus on binary affective classification. However, to study the affective states of consumers, it would be more interesting to go deeper into the classification and detect subtle affective changes in marketing. Furthermore, marketing scenarios may induce multiple emotions in customers. The phenomena of coexistence should be considered in affective tagging. We recommend that future studies should focus on two issues to develop a more accurate affective definition and conduct better forecasting: (1) they should aim for a deeper understanding of consumer ambivalence, characterized by the co-occurrence of positive and negative emotions (Kreibig and Gross, 2017; Hu et al., 2019); and (2) consider emotion dyads, namely, a mix of primary emotions, raised by Plutchik (1980).

The multidimensional and multimodal feature fusion can obtain better recognition performance. When studying EEG-affect relationships, EEG-based AC studies assume that EEG signals can sufficiently depict and predict human affective states. However, this hypothesis cannot always be assumed to be true because the relationship between physiological responses and psychological states could be very complex (Cacioppo and Tassinary, 1990; Hu et al., 2019). To achieve precise prediction and improved generalization, first, we suggest decreasing the abundant number of features from EEG signals and further perform feature selection and fusion. The most widely used features include differential symmetry, GFP, PSD, and ERPs. It might be the case that a fusion of features derived from different EEG signal types will lead to better recognition performance (Hakim and Levy, 2019). It is worth noting that future studies should be more cautious regarding the reliability and validity of "one-to-one" relationships (one affective state is associated with one and only one EEG feature) (Bridwell et al., 2018; Hu et al., 2019). Second, recent studies have revealed that multimodal frameworks can effectively increase emotion recognition accuracy and robustness compared to unimodal frameworks (Guixeres et al., 2017; Avinash et al., 2018; Kumar et al., 2019). The advantage of multiple modalities (for example, vision, sound, or smell) helps to increase the validity and usability since the weaknesses of one modality are offset by the strengths of another. Future studies may derive features from modalities other than EEG while collecting and analyzing data by using machine learning, natural language processing, and automatic speech recognition technology, evolving from unimodal analyses to multimodal fusion.

The use of portable wireless EEG devices and virtual reality (VR) technology can alleviate the lack of ecological validity in marketing studies. For EEG hardware devices, the whole-brain coverage, the time-consuming preparation procedure, and the

TABLE 1 | Summary of current findings on EEG-based affective computing in marketing.

Reference	Journal	Marketing substance	Affective states	EEG features	Method (classification accuracy)
Reeves et al., 1989	Human Communication Research	TV commercials	Valence	Hemispheric differences (alpha)	ANOVA
Ma et al., 2007	Neuroreport	Brand	Conflict	ERPs (N270)	ANOVA
Ohme et al., 2009	Journal of Neuroscience, Psychology, and Economics	TV commercials	Valence	Hemispheric differences (alpha)	*t* tests and Pearson's linear correlation
Chen et al., 2010	Biological Psychology	E-commerce products	Valence	ERPs (N500)	ANOVA
Handy et al., 2010	Journal of Cognitive Neuroscience	Commercial logos	Liking	ERPs (P1, N2)	ANOVA
Ohme et al., 2010	Journal of Economic Psychology	TV Commercials	Valence	Hemispheric differences (alpha)	ANOVA and *post hoc* tests
Vecchiato et al., 2010	Brain Topography	TV commercials	Pleasantness	GFP (theta, beta)	ANOVA
Vecchiato et al., 2011b	Medical,Biological Engineering and Computing	TV commercials	Pleasantness	PSD, ERD (alpha, theta)	*t*-test
Jones et al., 2012	Biological Psychology	Pricing	Anxiety	ERPs (FN400, P3, LPC)	ANOVA
Guo and Elgendi, 2013	Journal of Advanced Management Science	Recommender system for e-commerce	Valence	Spectral power (alpha, beta)	Pearson's linear correlation
Khushaba et al., 2013	Expert Systems with Applications	Food property	Liking	PSD, ERS (delta, theta, alpha, beta, gamma)	Phase locking value
Lin et al., 2014	Frontiers in Neuroscience	Music	Valence, arousal	PSD, DLAT, DCAU, MESH (delta, theta, alpha, beta, gamma)	SVM (valence: 82.5%; arousal: 79.1%)
Kuan et al., 2014	Journal of Management Information Systems	Group-buying information	Valence, liking	Hemispheric differences (alpha)	ANOVA
Vecchiato et al., 2014	Cognitive Computation	TV commercials	Valence, arousal	PSD (alpha), IAF (alpha)	*t* test
Friedman et al., 2015	International Conference on Affective Computing and Intelligent Interaction	TV commercials	Valence	Spectral power hemispheric differences (delta, theta, alpha, low beta, high beta)	MANOVA, SVM (77.3%), LMT (81.2%)
Pozharliev et al., 2015	Journal of Marketing Research	Luxury goods	Arousal	ERPs (P2, P3, LPP)	ANOVA
Telpaz et al., 2015	Journal of Marketing Research	Consumer goods	Liking	ERPs (N200), spectral power (theta)	*t* tests and spearman correlation
Venkatraman et al., 2015	Journal of Marketing Research	TV commercials	Valence, arousal	Occipital activity and frontal asymmetry (alpha)	SUR regression
Yang et al., 2015	Journal of Physiological Anthropology	TV commercials	Happiness, surprise	PSD (delta, theta, alpha, low beta, high beta, gamma)	ANOVA, FLDA (happiness: 88.6%; surprise: 87.5%)

(Continued)

TABLE 1 | Continued

Reference	Journal	Marketing substance	Affective states	EEG features	Method (classification accuracy)
Berčík et al., 2016a	Periodica Polytechnica Social and Management Sciences	Music preferences	Pleasantness	Spectral power (alpha, beta)	Descriptive statistics
Berčík et al., 2016b	Appetite	Store illumination	Valence, arousal, dominance	Spectral power (alpha, beta)	Non-parametric Wilcoxon signed rank test
Chew et al., 2016	Cognitive Neurodynamics	Industrial design	Liking	ERS/ERD (alpha, theta, delta)	SVM (79%), KNN (80%)
Gupta and Falk, 2016	Neurocomputing	Music videos	Valence, arousal, dominance, liking	EEG graph-theoretic features	SVM (valence: 64%; arousal: 64%; dominance: 59%; liking: 64%), RVM (valence: 65%; arousal: 68%; dominance: 63%; liking: 67%)
Horska et al., 2016	Agricultural Economics	Consumer preferences	Valence	Wave fluctuating tendency	Kruskal–Wallis test
Lee, 2016	Journal of Business Research	Willingness to pay	Valence	Spectral power (theta)	sLORETA
Gauba et al., 2017	Neural Networks	TV commercials	Valence	Statistical mean of band oscillations of each electrode	RF (68%)
Guixeres et al., 2017	Frontiers in Psychology	Online commercials	Liking	GFP (delta, theta, alpha, beta, Gamma)	ANN (82.9%)
Lobato and Garza, 2017	IEEE Latin America Transactions	Purchasing behaviors	Liking	Hemispheric differences (alpha)	ANN (76%)
Yadava et al., 2017	Multimedia Tools and Applications	E-commerce products	Liking	Band oscillations (delta, theta, alpha, beta, Gamma)	HMM (70.3%)
Avinash et al., 2018	Procedia Computer Science	Advertisement jingles	Valence	Frontal asymmetry (theta)	KNN (100%), FLDA (90%)
Jin et al., 2018	Frontiers in Human Neuroscience	Eco-labeled products	Valence	ERPs (P2, N2)	ANOVA
Wei et al., 2018	Frontiers in Neuroscience	Commercials	Valence	Wavelength, signal quality (delta, theta, low alpha, high alpha, low beta, high beta, low gamma, high gamma)	SVM (77.3%)
Kumar et al., 2019	Information Fusion	E-commerce products	Valence	Spectral power (delta, theta, alpha, beta, Gamma)	RF (48%), ABC + RF (72%)
Aldayel et al., 2020	Applied Sciences	Purchasing behaviors	Pleasantness	PSD (theta, alpha, beta, gamma)	DNN (94%), RF (92%), SVM (62%), KNN (88%)
Shang et al., 2020	Psychology Research and Behavior Management	Webpage layout	Valence	ERPs (P2, LPP)	ANOVA

ANOVA, analysis of variance; ERPs, event-related potentials; GFP, global field power; PSD, power spectral density; SVM, support vector machine; IAF, individual alpha frequency; MANOVA, a multivariate analysis of variance; LMT, logistic model tree; FLDA, Fisher linear discriminant analysis; ERS/ERD, event-related synchronization/desynchronization; KNN, K-nearest neighbors; RVM, relevance vector machine; sLORETA, standardized low-resolution electromagnetic tomography; RF, random forest; ANN, artificial neural network; HMM, hidden Markov model; ABC, artificial bee colony; DNN, deep neural network.

prohibitive cost of a professional headset with wet electrodes make it impractical and difficult to transfer the laboratory to real-world applications in marketing. A group of recent studies has confirmed the feasibility of using consumer-level EEG headsets for AC with promising results. For example, the widely used wireless EPOC headset (e.g., Kuan et al., 2014; Lin et al., 2014; Friedman et al., 2015; Yang et al., 2015; Gauba et al., 2017; Yadava et al., 2017; Kumar et al., 2019), due to its light weight, low price, and ease of use, shows promise. Studies on the EPOC headset seem to agree that it can be applied to acquire reliable EEG signals in marketing, but researchers should pay attention to its relatively low signal-to-noise ratio and poor signal stability (Friedman et al., 2015). We suggest that researchers evaluate the performance of consumer-level devices using the standard testing procedures proposed by Hu et al. (2019). In addition, to bridge the gap between the laboratory environment and real market scenarios, the use of VR is an important trend that can effectively enhance the experience of immersive sensation. It enables consumers to get a direct, intuitive, and concrete understanding of the appearance, quality, and performance of products (Guo and Elgendi, 2013). Furthermore, VR makes it possible to simulate and assess retail and consumption environments under controlled laboratory conditions (Marín-Morales et al., 2017), allowing the isolation and modification of variables in a cost-effective manner.

Studying interactions among multiple customers is critical for understanding the marketing ecosystem, which consists of interrelated trends that shape consumer behaviors. Most AC studies in marketing have concentrated mainly on a single consumer's EEG activity and may ignore the socio-affective interaction and processes related to consumer behavior (Hasson et al., 2012). The EEG-based hyperscanning technique [for a recent review, see Liu et al. (2018)] provides a way to explore dynamic brain activities between two or more interactive customers and their underlying neural affective mechanisms. In previous hyperscanning studies, interpersonal neural synchronization (INS) has been verified to be a crucial neural marker for different kinds of social interactions, such as communication (Stephens et al., 2010), collaborative decision making (Montague et al., 2002; Hu et al., 2018), and imitation (Pan et al., 2017). As consumer behavior is inherently social and interactive in nature, EEG-based INS could be used to study the biological mechanism for shared intentionality of consumption, panic buying, collective emotion, and group purchase.

AUTHOR CONTRIBUTIONS

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

FUNDING

This work was supported by Grant No. 2020M671819 from the China Postdoctoral Science Foundation. This work was also supported by Grant No. 111002-AC2001 from the Major Scientific Project of Zhejiang Lab.

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

The handling editor declared a shared affiliation with TL and GP at the time of review.

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frontiers in Psychology

BRIEF RESEARCH REPORT
published: 23 March 2021
doi: 10.3389/fpsyg.2021.653011

Touching to Feel: Brain Activity During In-Store Consumer Experience

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To gain a deeper understanding of consumers' brain responses during a real-time in-store exploration could help retailers to get much closer to costumers' experience. To our knowledge, this is the first time the specific role of touch has been investigated by means of a neuroscientific approach during consumer in-store experience within the field of sensory marketing. This study explores the presence of distinct cortical brain oscillations in consumers' brain while navigating a store that provides a high level of sensory arousal and being allowed or not to touch products. A 16-channel wireless electroencephalogram (EEG) was applied to 23 healthy participants (mean age = 24.57 years, SD = 3.54), with interest in cosmetics but naive about the store explored. Subjects were assigned to two experimental conditions based on the chance of touching or not touching the products. Cortical oscillations were explored by means of power spectral analysis of the following frequency bands: delta, theta, alpha, and beta. Results highlighted the presence of delta, theta, and beta bands within the frontal brain regions during both sensory conditions. The absence of touch was experienced as a lack of perception that needs cognitive control, as reflected by Delta and Theta band left activation, whereas a right increase of Beta band for touch condition was associated with sustained awareness on the sensory experience. Overall, EEG cortical oscillations' functional meaning could help highlight the neurophysiological implicit responses to tactile conditions and the importance of touch integration in consumers' experience.

Keywords: EEG, touch, consumer experience, in-store research, wireless system, consumer awareness

OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *13 January 2021*
Accepted: *16 February 2021*
Published: *23 March 2021*

Citation:
Balconi M, Venturella I, Sebastiani R and Angioletti L (2021) Touching to Feel: Brain Activity During In-Store Consumer Experience. Front. Psychol. 12:653011. doi: 10.3389/fpsyg.2021.653011

INTRODUCTION

Aware that the consumer's behavior is the complex result of a multifaceted interaction between the organism and its environment (Holbrook and Hirschman, 1982), customer experience has been defined as "the aggregate of feelings, perceptions and attitudes formed during the entire process of decision-making and consumption chain [. . .] leading to cognitive, emotional, sensorial and behavioral responses" (Jain et al., 2017) and can be grounded in the theory of organism response by Mehrabian and Russell (1974), for which the consumer's responses (i.e., approach or avoidance) are determined by the interaction between stimulus and organism (i.e., consumer's emotional state of pleasure, arousal, and dominance) (Mehrabian and Russell, 1974). The implicit processing underlying the interaction between stimulus and organism can be studied by means of

neurophysiological tools applied during the consumer's experience; indeed, these tools can help to obtain relevant information on the ongoing covert sensory experience while touching products that are not directly achievable with classical self-report questionnaire or scale.

Within the frame of sensory marketing, previous research showed the importance of the sense of touch during the in-store consumer experience, considering both positive consequences and negative effects (i.e., tactile contamination) of touching products (Citrin et al., 2003; McCabe and Nowlis, 2003; Argo et al., 2006; Peck and Childers, 2006; Peck and Wiggins, 2006; Peck and Shu, 2009; Peck and Johnson, 2011). Indeed, the sense of touch has often been considered as a booster of the consumer's experience, able to predict the will of purchasing a good, and, nowadays, the absence of tactile stimulation (i.e., the inability to handle merchandise) has been identified as one of the most well-known obstacles of online Web shopping experience (McCabe and Nowlis, 2003) that must be replaced by other positive intervening factors as the promotion of a positive mood state and/or the use of a touch interface while surfing the e-commerce (Yazdanparast and Spears, 2013; Chung et al., 2018).

To determine individual differences related to the specific need of touching products, before, a "Need For Touch" scale (Peck and Childers, 2003a,b) has been designed, and it includes two different dimensions: one more instrumental, and the other one related to the compulsive and emotional components of touch. These individual differences have been argued to influence the impact of humans touching products and products touching products (Krishna, 2012). Indeed, touch has widely been considered strictly related to emotion domain, given that physiologically, even skin surface is dedicated to the affective response coding (e.g., C Tactile nerve fibers; Spence and Gallace, 2011). Spence and Gallace (2011) argued that touch is also likely to provide "a less noisy estimate of a product's hedonic value" than other senses, and, accordingly, it has been highlighted that touch is connected to information and feelings on a product through physical and psychological interactions (Hultén, 2011).

However, there is still a lack of studies investigating the psychological dimensions and emotional aspects involved in sensory consumers' experience in-store by employing a neuroscientific approach and, in particular, touch is the least studied sense in the neuromarketing field. Nevertheless, we agree with previous research that this sense plays a key role in the emotional aspects involved during the sensory experience of the customer (Hultén, 2011, 2012, 2013; Klatzky, 2011).

For this reason, we conducted an empirical study applying electroencephalogram (EEG) to measure the involvement of senses, specifically touch, elicited by sensory cues during customers' store exploration. The use of an EEG wireless technology implies the capability to record brain waves at very small-time intervals, in the order of milliseconds, while consumers are exploring space. This is extremely valuable, considering the speed at which we acquire information through our senses and the speed of our thoughts (subseconds). Besides a good temporal resolution, within the neuromarketing field, the advantages of using EEG have been previously highlighted also by other scholars (Vecchiato et al., 2011); indeed, EEG wireless devices are portable, relatively low cost, robust, and suitable for evaluating marketing stimuli in an ecological environment if compared to other neuroscientific tools requiring a static setup (such as functional magnetic resonance imaging or magnetoencephalogram).

Overall, the aim of our study is to gain a deeper understanding of customers' neural activations related to emotional processing following exposure to certain sensory stimuli during an in-store exploration and to answer the call for papers launched in recent years within the field of sensory marketing asking for more impactful research (Krishna, 2012). Indeed, prior studies demonstrate that there is an impact of the retail space on the shopper's sensory and social stimulations, leaving the consumer pleasured and aroused during the shopping experience (Turley and Milliman, 2000).

Our experimental and extremely ecological setting was the inside of one store belonging to a popular cosmetics chain, well-known for the use of bright colors to stimulate sight, of high-volume pop music to stimulate hearing and positive feelings, and of perfumes deriving from the products rigorously exposed without packaging (characterizing the brand value aimed to provide a multisensory experience). In addition, customers are also given the chance to easily touch and try all the products exposed, thus providing a higher level of sensory arousal. With the purpose of exploring a single sense experience and the relative impossibility to use the others, selective sensory deprivation supports (earplugs for ear, plugs for the nose, and the instruction to "do not touch") were applied on the person during a free shopping experience. The field of cosmetic was functional for exploring sensory integration/deprivation for two reasons: (i) the intrinsic features of cosmetic items are known to appeal to all five senses; (ii) if, during the analysis of a cosmetic product, consumers' senses are positively activated, this will possibly result in a positive appraisal of the perceived quality of the product and lead to an approach behavior due to the product's emotional connection (Theofanides and Kerasidou, 2012).

Specifically, cortical oscillations (EEG waves) observed during different conditions of sensory stimulation inside the store and their functional meaning were considered in order to understand the relevance of the presence and the absence of tactile stimulation in consumer experience. Within the neuroscientific Dual Systems model (Davidson, 1992) that connects emotional aspects and behavioral tendency to the anterior cerebral activation, a right frontal greater neural activity is associated with negative events, inhibitory control processing, and withdrawal-related behavior, while the presence of a left frontal neural activation reflects a positive emotional processing and an approach-related behavior.

According to this theoretical account and previous literature (Balconi and Mazza, 2010; Balconi and Bortolotti, 2012; Balconi et al., 2014a), we expected different neural oscillations based on ongoing emotional and cognitive processes while depriving or maintaining the sense of touch (Başar et al., 2001; Brovelli et al., 2004). In particular, for the non-touch condition – requiring subjects' behavioral adaptations to this deprivation –, it was hypothesized a poorer sensory experience, characterized by low frequency bands frontal left activation (Cavanagh and Shackman,

2015). On the other hand, it was supposed that the use of the sense of touch can be considered a positive condition with enhanced sensory processing reflected by higher-frequency band activation in sensorimotor brain regions. Moreover, the presence of unpredictable and possible compensatory neural mechanisms due to the isolation of a sense was considered.

MATERIALS AND METHODS

Sample

A total of 23 Caucasian right-handed healthy participants were engaged in the experiment (five males; mean age = 24.57 years, SD = 3.54). Inclusion criteria were as follows: (1) interest in cosmetics, (2) not being a frequent customer of the store used as the experimental setting, and (3) normal or corrected-to-normal hearing and vision. Exclusion criteria were the presence of sensory and cognitive deficits, a history of psychiatric or neurological diseases, and ongoing concurrent therapies based on psychoactive drugs that can alter central nervous system functioning. No compensation was provided for their participation in the study. One participant was excluded from the statistical analysis due to the high presence of movement artifacts.

The study has been designed following the principles of the Declaration of Helsinki. Procedures and methods were approved by the Ethics Committee of the Department of Psychology, Catholic University of the Sacred Heart of Milan, Italy. Subjects gave written informed consent for their participation in the study.

Procedure

Participants have been introduced in a neutral point of the store (warehouse), where non-invasive EEG sensors were placed, and then they were guided inside the store. Sensory deprivation supports were applied before starting the store exploration. Subjects were equally divided into two conditions based on the senses that subjects could use: (1) Touch (participants can use touch); (2) Non-Touch (participants can see, hear, and smell, with the instruction "do not touch"). The sight was kept as a constant to let participants explore the ecological setting (that is the store) freely. They were assigned to only one condition in order to avoid order and habituation effects. After the placement of the sensory deprivation supports, subjects were informed that they had time from a minimum of 5 min to a maximum of 15 min to explore the store freely, according to their experimental condition. During the whole experiment, EEG cortical activity was recorded.

Electroencephalogram Recording and Neural Data Reduction

During store exploration, EEG activity was collected *via* an EEG wireless System (Live-Amp) and processed *via* Analyzer2 software (Brain Products GmbH, Gilching, Germany). The montage included 15 active electrodes (Fp1, Fp2, F3, Fz, F4, T7, C3, Cz, C4, T8, P3, Pz, P4, O1, O2; placement according to the 10-20 International System; Jasper, 1958). Electrode impedance was monitored for each subject prior to data collection and kept under 5 kΩ. Data were acquired using a sampling rate of 250 Hz and then filtered offline with a 0.5–45-Hz IIR bandpass filter (slope = 48 db/octave). Data were then segmented and visually inspected for ocular, muscle, and movement artifacts. Fast Fourier Transform (Hamming window, resolution = 0.5 Hz) was applied to artifact-free segments to compute the average power spectra. Finally, average power for the main EEG frequency bands (Delta = 0.5–3.5 Hz, Theta = 4–7.5 Hz, Alpha = 8–12.5 Hz, Beta = 13–30 Hz) were extracted (see Harmony, 2013; Balconi et al., 2019, for frequency bands range).

Data Analysis

A set of mixed repeated measures ANOVAs with independent within-factors Region Of Interest (ROI) (3: Frontal [F3; F4], Central [C3; C4], and Parietal [P3; P4]) and Laterality (2: Left and Right) and as between factors the Condition related to sense of touch isolation or deprivation (2: Touch vs. Non-Touch) was applied on dependent EEG measures. This mixed repeated measures ANOVA was performed for each frequency band (Delta, Theta, Alpha, Beta) in order to highlight the differences between two conditions: the isolation of a sense (only the sense of touch allowed) and the deprivation of the same (only to touch was not allowed). *Post hoc* comparisons were applied to the data in case of significant effects. Simple effects for significant interactions were further checked *via* pairwise comparisons, and Bonferroni correction was used to reduce multiple comparisons potential biases. For all the ANOVA tests, the degrees of freedom have been corrected using Greenhouse–Geisser epsilon where appropriate. Furthermore, the normality of the data distribution was preliminarily assessed by checking kurtosis and asymmetry indices. The size of statistically significant effects has been estimated by computing partial eta squared (η^2) indices.

RESULTS

Delta and Theta Low-Frequency Bands

As shown by ANOVA for Delta band, interaction effect Condition × Laterality × ROI was found [$F_{(2, 22)} = 5.49$, $p = 0.012$, $\eta^2 = 0.33$]. *Post hoc* pairwise comparisons revealed increased Delta power in left frontal area (F3) for the Non-Touch condition compared to the Touch condition [$F_{(1, 22)} = 5.61$, $p = 0.037$, $\eta^2 = 0.33$] (**Figures 1A,B**). For Theta band, interaction effect Condition × Laterality × ROI was found [$F_{(2,22)} = 7.77$, $p = 0.004$, $\eta^2 = 0.41$]. *Post hoc* pairwise comparisons revealed increased Theta power in the left frontal area (F3) for the Non-Touch condition compared to the Touch condition [$F_{(1, 22)} = 21.92$, $p = 0.001$, $\eta^2 = 0.66$] (**Figures 1C,D**).

Beta Band

For Beta band, an interaction effect Condition × Laterality × ROI was found [$F_{(2, 22)} = 3.82$, $p = 0.038$, $\eta^2 = 0.25$]. *Post hoc* pairwise comparisons revealed increased Beta power in the right frontal area (F4) for Touch condition compared to Non-Touch condition [$F_{(1, 22)} = 5.11$, $p = 0.045$, $\eta^2 = 0.31$) (**Figures 1E,F**).

DISCUSSION

The aim of the present study was to explore customers' cortical response (brain oscillations) related to the presence and the

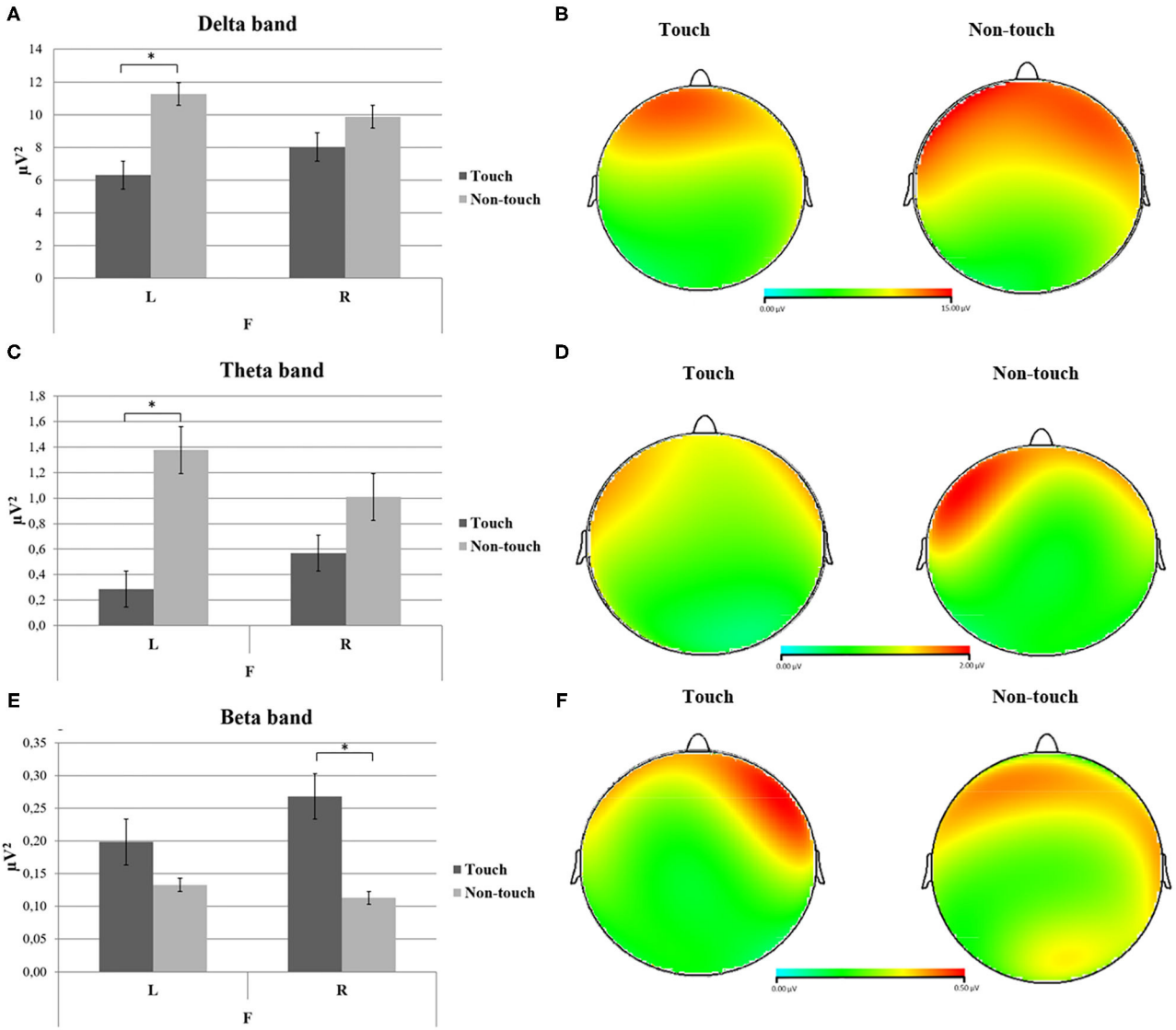

FIGURE 1 | (A–F) Electroencephalogram (EEG) oscillatory activity (power values) over left and right frontal sides in response to Touch- and Non-touch-related conditions. **(A)** Bar graph shows significant differences for delta power in the left frontal area between touch and non-touch conditions. **(B)** Delta EEG power representation of touch condition (left head) compared to non-touch condition (right head). **(C)** Bar chart displays significant differences for theta power in the left frontal area between touch and non-touch conditions. **(D)** EEG theta power display for touch (left head) compared to non-touch condition (right head). **(E)** Bar chart shows significant differences for beta power in the right frontal area between touch and non-touch conditions. **(F)** Beta power EEG display for touch condition (left head) compared to non-touch condition (right head). For all bar charts, stars mark statistically significant pairwise comparisons, bars represent ±1 SE. For all EEG head displays, red represents the increase of power for each frequency band.

absence of tactile experience during a free in-store navigation. Indeed, to isolate different conditions of sensory fruition helped us to deepen the knowledge on the role of the sense of touch in consumers' experience.

The performed frequency bands analysis contributed to underline the following main results connected to the role of frontal brain areas when cognitively processing the in-store exploration (in this case corresponding to the fruition of cosmetic products) with and without tactile sensory insights. Firstly, a higher presence of Delta and Theta band activity mainly lateralized on left frontal areas for the Non-Touch condition was found. In this condition, participants could explore the store freely using the senses of sight, hearing, and smell, yet with the instruction not to touch products. Secondly, an augmented Beta band power for the Touch condition was detected in the right anterior regions.

According to previous literature, this evidence can be discussed mainly focusing on the cognitive aspects related to the

functional meaning of the detected frequency bands. Regarding our first results, the high presence of low-frequency bands in frontal anatomical structures could be considered mainly as a marker of cognitive operations involved during the situation in which a tactile exploration of products was not allowed. Indeed, starting from the cognitive features related to the manifestation of Theta band, previous studies identified that complex bimodal sensory stimulation increase the frontal processing in this band range (Başar et al., 2001). More broadly, an "orienting" function of this frequency band has been recognized, since its power was also observed in case of a coordinated response indicating alertness and readiness to process information during exploration, searching, and motor behavior (Başar, 1999); that is, theta EEG power typically increases with increasing attentional demands and/or task difficulty or uncertainty (Başar-Eroglu et al., 1992; Cavanagh and Shackman, 2015). In addition, Theta power also increases over mid- and lateral-frontal areas for events that involve a need for cognitive control, such as novel stimuli, conflicts, and errors (Cavanagh and Frank, 2014). Thus, one possible explanation could be that the experimental condition in which participants experienced the free exploration of the store without the chance to touch products, but maintaining the other multiple sensory stimulations, could have involved a sort of "sensory uncertainty" with the absence of the most salient sense (touch), resulting in an anomalous gestalt perception for the perceiver who was not able to gain a full perceptual understanding of the stimulus and, consequently, needs much more cognitive effort for processing it.

Conversely, limited data exist on the functional meaning of Delta band modulation and roughly similar to those mentioned for Theta oscillation, i.e., cognitive processing. In previous basic research by Başar-Eroglu et al. (1992), the amplitude of delta response was found to be considerably increased during oddball paradigms. And, accordingly, it has been concluded that Delta activity is related to signal detection and decision-making. In line with this, Knyazev (2007) showed that delta power depends on the activity of motivational systems and participate in stimulus salience detection (Knyazev, 2007). Moreover, Balconi et al. (2015) found that delta modulations were found to be related to arousing power of stimuli in right and left frontal localizations, regardless of the stimulus valence. Therefore, we concluded that, taken together, Theta and Delta increased activity may be responsive to a process of signal detection of the stimuli encountered during the store navigation; however, the absence of tactile contact could have given rise to a situation of incomplete environmental perception that alerted the consumers on the need for cognitive control on their experience. Further studies will need to explore the emotional meaning of the presence of Delta and Theta frequency bands in the left hemisphere during a condition of sensory deprivation.

Concerning our second result, a Beta band cortical pattern was found to be more lateralized on the right frontal hemisphere, suggesting a greater attentional focus on the touch condition that could have brought the subjects to a higher conscious activation. One possible explanation is that this experimental condition in which consumers are allowed to touch the products could have induced to an attentional activation mainly focused on the tactile and visual aspects of the product. Previous literature highlighted how frontal neural activity in the Beta band have been linked to sensorimotor network-enhanced activity together with the maintenance of the cognitive state (Brovelli et al., 2004). Regarding the functional role of Beta band activity during cognitive and perceptual processing, (Engel and Fries, 2010) determined that Beta power can be enhanced if there is the priority to maintain a cognitive state over potential new signals considered as distractive (Engel and Fries, 2010). More generally, a greater frontal right hemispheric activation was demonstrated to reflect also the inhibitory control processes (Garavan et al., 1999; Aron et al., 2014). Thus, it has been possible to suppose that, within our touch condition, a right Beta band activity in frontal areas is associated with sustained attention and maintenance of the cognitive set that overrides the effect of potentially novel, or unexpected, external events, providing an "augmented" and aware sensory and cognitive experience derived by the possibility to touch the products.

In addition, in evolutionary terms, the sense of touch (and haptic more in general) has ancestral roots and covers a central role within the sensory system, both phylogenetically and ontogenetically. Previous evolutionary studies show that even infant macaque monkeys prefer to physically approach a surrogate soft cloth mother (closer to their haptic representation of mother) than a wire mother (Harlow, 1958). Specifically, even if the wire mother provides nutrition, the cloth mother provides a warm and more coherent experience, thus being considered the favorite by the animal infants. This has been found to be true also for human infants, for which the physiological need for food and the instrumental role of the nutritive mother can be bypassed by the need for physical touch and effective contact (Montagu, 1971).

In the field of neuromarketing, the importance of touch, especially for clothing and fabric retail, has previously been recognized, and retailers use different marketing strategies aware and guided by the importance of touch (Citrin et al., 2003; McCabe and Nowlis, 2003). Indeed, some store chains make the displayed merchandise difficult to touch or, on the contrary, easy to touch on the basis or their marketing strategy. Our results stressed the idea that touch is a sense that should be maintained in retail strategies because it is able to provide the consumers a full and complete cognitive experience of the product, even when other senses are absent or temporarily isolated.

However, so far, no previous studies investigated the specific role of touch by means of EEG power spectral analysis within the field of sensory marketing, specifically when exploring cosmetic products. For this reason, future research will need to deepen our insights and investigate if they can be broadly transferred into the wide context of sensory marketing, in which we believe that touch can cover a discriminating role for consumers' experience exploring cosmetic products.

Moreover, further studies will be necessary to investigate the lateralization effect we found in relation to the different frequency bands and the possible specific role of Delta and Theta oscillations in left frontal structures as a possible marker of processing the emotional valence of consumers' experience. Indeed, frontal and prefrontal cortex lateralization has been

previously related to cognitive control over emotional stimuli and emotional behavior in basic research and in studies on cross-modal integration of emotional cues (Balconi et al., 2015; Balconi and Vanutelli, 2016). In past neuromarketing studies, a left prefrontal cortex activation toward commercial advertising was interpreted as an index of positive emotions and consumers' preference (Balconi et al., 2014b; Leanza and Balconi, 2017).

So far, to our knowledge, there is only one basic research on the valence of tactile stimulation showing an increase in right temporoparietal and frontal electrodes in the beta range for pleasant products compared to unpleasant ones (Singh et al., 2014). This study suggested the possible usefulness of the Beta band to more directly measure affective states and higher-order cognitive sensory aspects in a wide range of areas of interest where touch is involved, such as neuromarketing and consumer research (Solnais et al., 2013). Since these previous studies have been applied in different contexts from the cosmetic field, caution is needed in affirming that touch and non-touch conditions can both be characterized by consumers' positive emotional responses, and further research is needed to disentangle emotional valence of the experience.

To summarize, we examined customers' cortical oscillations recorded with the aid of an EEG wireless device during a free in-store navigation. The partial isolation of different sensory fruitions helped us to discuss the results in the light of the presence or deprivation of the ability to touch cosmetic products, thus exploring the role of this sense in consumers' experience.

The performed analysis allowed to determine some main results connected to the presence of specific frequency bands in frontal brain areas when exploring a store with and without the chance to acquire tactile sensory insights. Firstly, a higher presence of Delta and Theta band activity on frontal areas for the non-touch condition was found and interpreted as a need for cognitive control perhaps caused by an incomplete perceptual understanding deriving from the absence of the sense of touch. Secondly, an increase of Beta power for the touch condition was detected in the brain anterior regions, suggesting a cognitive state of sustained attention and enhanced network activity of higher-order somatosensory areas encoding perhaps the sensory aspects of the stimuli. The salience of touch was finally discussed at the light of its evolutionary importance and as a key sense able to provide consumers a complete and coherent perception of their experience.

Despite our study providing novel results exploitable in the sensory marketing field, it also presented some limitations to take into account by future studies. Since our sample size was limited and not balanced for gender variable, it is possible that some gender differences be considered in terms of experiencing the cosmetic store exploration; in one previous study on cosmetics and brain activation, only women were considered (Tanida et al., 2017). Moreover, this study is limited to the cosmetic products field, and no previous studies examined this area of interest *via* EEG technology. To our knowledge, only one study focused on the evaluation of pleasure–displeasure induced by the application of a cosmetic product in terms of cerebral activation exploiting near-infrared spectroscopy (Tanida et al., 2017). In addition, the present study adopted a different EEG methodology compared to the literature on this topic that is mainly based on event-related EEG approach. Therefore, future studies are needed to strengthen both the experimental procedure and present findings.

Overall, the potential of using neuroscientific tools in sensory marketing is still not so widespread, and for this reason, we suggest that future studies could consider the use of EEG wireless device to explore the wider role of touch in consumers' experience in various ecological contexts.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The study involving human participants was reviewed and approved by Department of Psychology, Catholic University of the Sacred Heart of Milan, Italy. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MB, IV, RS, and LA contributed to the conception and design of the study. MB and LA wrote the first draft and each section of the manuscript. All authors contributed to manuscript revision and read and approved the submitted version.

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

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frontiers in Communication

ORIGINAL RESEARCH
published: 26 March 2021
doi: 10.3389/fcomm.2021.659484

Strategic Communication and Neuromarketing in the Fisheries Sector: Generating Ideas From the Territory

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Background: Globalization and technological progress has changed the relationships among fisheries, society and markets. The industrial primacy has led, among others, to the marginalization of fishermen and the deletion of local culture. It followed a loss of the conventional link between territory and traditions, with a change in consumer behavior.

Aim: The purpose of this study is to investigate the way through which the communication of territoriality of fish products influences the consumers' quality perception, their willingness to pay and the exploration of packaging, in the Italian context.

Method: In order to obtain quantitative and qualitative data on visual paths (the series of fixations and saccades) and areas of interest (AOI) of the analyzed packaging, gaze data were recorded. AOI permits to define regions of a visual stimulus and to link eye-movement measures to parts of the used stimulus. This study used AOI in order to measure Spent Time (the amount of time that consumers have spent looking at a particular AOI) and Entry Time (the time passed from the moment of the first fixation in a particular AOI) on brands and on products.

Results: The results of the drivers identified crucial points for the future communication of fish products and the promotion of the territory. In particular, the analysis lays the foundations for a reorganization of the approach to the creation of product packaging, through greater attention to detail and the intrinsic values that this can express.

Conclusion: The use of neuromarketing techniques has proved to be valid in identifying what is the main information that is processed for the evaluation of the product also considering the role played by emotions.

Keywords: neuromarketing, territory, fisheries sector, packaging, communication/eye tracker

OPEN ACCESS

Edited by:
Paula Benevene, Libera Università Maria SS. Assunta, Italy

Reviewed by:
Ilaria Buonomo, Libera Università Maria SS. Assunta, Italy
Dorota Kanafa-Chmielewska, University of Wrocław, Poland

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Communication

Received: *27 January 2021*
Accepted: *02 March 2021*
Published: *26 March 2021*

Citation:
Russo V, Milani Marin LE, Fici A, Bilucaglia M, Circi R, Rivetti F, Bellati M and Zito M (2021) Strategic Communication and Neuromarketing in the Fisheries Sector: Generating Ideas From the Territory. Front. Commun. 6:659484. doi: 10.3389/fcomm.2021.659484

INTRODUCTION

Globalization and technological progress have changed the relationships among agriculture, fisheries, society and markets. The industrial primacy of consumption styles, supported by advertising, has led to the marginalization of farmer-fishermen, the loss of agricultural and maritime biodiversity, the deletion of history/memory/culture, and the belief that food is produced

in factories. It followed a food homologation and the loss of the conventional link between territory and traditions, with a change in consumer behavior (Philippidis and Sanjuán, 2003).

On the one side, consumers appreciate sobriety and social values both in consumption and communication, giving up the sensorial over excitation, typical of the period preceding the crisis. On the other side, organizations moved from profit-oriented to profit/social-value-oriented strategies: as a matter of fact, the corporate social responsibility has been transformed into a constituent value of the organizational culture, from a tool for the construction of its Corporate Image to the essence of its Organizational Identity (Dahlsrud, 2008). One of the main elements depicting this change and renewed identity is the regional marketing, which is linked to the country image and its development contributes to the regional economic progress (Bagautdinova et al., 2012).

Generally, the marketing literature has focused on the concept of authenticity, considered as one of the main drivers in the consumers' attitude toward brands and products (Holt, 2002; Napoli et al., 2014). The concept of authenticity is closely related to the origin of products (Tregear et al., 1998; Philippidis and Sanjuán, 2006), so that emphasizing the regional origin of food is becoming an alternative marketing model to the traditional one that focuses on homogeneous production and mass consumption (Domański and Bryła, 2013; Bryła, 2015). Indeed, the sense of tradition and authenticity conveyed by any reference to the region of origin are considered effective drivers to purchase (Bell and Valentine, 1997; Cacciolatti et al., 2015).

In this view, the use of tradition is growing in marketing: it refers to the consumers' need to trust and to have a point of reference; moreover, it overcomes manufacturing and relates to the regional characteristics building products image and perception on tradition and localization (Bryła, 2015). Therefore, it is important to understand those characteristics supporting the solidity of products. Territoriality is suggested to be the most appropriate characteristic due to the cultural relation between food and context and it can be applied to regional and local contexts (Sonnino, 2007). In this view, the territorial issue can be considered itself a potential product, since territories become an element of competition attracting consumers (Anholt, 2007).

Specifically, the packaging and labels are two essential instruments of the marketing strategy that can be applied to the communication of territoriality and tradition. In fact, both ensure that consumers have the essential information to make an informed food choice; moreover, they are touch points, that is moments of contact between company and consumers influencing their experiences and perceptions (De Oliveira et al., 2015).

A constantly growing interest in the fields of label, packaging and consumer neuromarketing has been occurring in recent years. With reference to these consumer studies, it is essential to note that in the last few decades, an overcoming of the traditional model based on the *homo economicus*, due to the extension of the concept of "unconscious" to the economy, has been occurring (Plassmann et al., 2007). In fact, the current complexity of the food market requires a marketing approach integrating traditional and neuroscience techniques. Traditional techniques are based on a rationalistic consumer conception model and are limited to collecting information mediated by the cognitive filter. Whereas, the neuroscientific approach makes possible to grasp the complexity of consumer's decision-making and attentive processes measuring implicit and emotional responses to marketing messages (Damasio, 2000).

Therefore, the use of the neuromarketing techniques would allow a better understanding of this complex phenomenon since it detects the underlying cognitive and affective processes. In fact, neuromarketing adapts neuroscientific models and theories to the marketing objectives, integrating behavioral models deriving from the consumer psychology (Plassmann et al., 2012). The main research areas of this discipline are the perceptive and cognitive consumers' processes; it investigates neural correlates of human behavior related, among others, to consumption attitude, emotion and behavior. Through this interdisciplinary approach, it is possible to obtain more detailed information on cortical processes that occur during the consumer's exposition to marketing stimuli (Martinez, 2011). Neurophysiological and biological processes, which are responsible for consumer decision making and behavior, can thus be investigated and provide more accurate information underlying consumer preferences, values and emotions (Meyerding and Mehlhose, 2020). This is especially true for the hidden processes that are difficult to investigate because they are below the level of consumer awareness or difficult to verbalize (Plassmann et al., 2012).

The importance of using these innovative techniques, even together with those of traditional marketing research, lies in directly detecting the involuntary activities of consumers, thus permitting researchers to elude a relevant obstacle: the cognitive dimension that predominates in responses to marketing stimuli.

One of the most used instruments is the eye tracker, which precisely tracks the location and duration of visual attention. The overabundance of images and sensory stimuli makes the eye tracking an effective tool for understanding the mechanisms underlying the consumer choice to gaze specific points in the label (De Oliveira et al., 2015). Despite the eye tracker's usefulness in identifying ways in which labels and packaging can be modified to refine consumers' capacity to detect and effectively utilize information, research mainly focuses on the nutritional labels (Graham et al., 2012).

The purpose of this study is to investigate the way through which the communication of territoriality influences the quality perception, the willingness to pay and the exploration of packaging, among the fisheries sector in the Italian context. Improving the communication of aspects such as the products' territoriality and sustainability could be a way for the regions, in particular for those in the South of Italy, to bridge the economic gap with the Northern regions, and raising for the benefit of an entire nation markets. Indeed, advantages in emphasizing the territorial origins of a product are not only limited to producers but can also results in a distribution of the economic rents for a large group of stakeholders (Pecqueur, 2001; Tregear et al., 2004). As stated by Bagautdinova et al. (2012, p. 179), "regional marketing is a tool for shaping the internal advantages of the region, investment and economic development factors, increasing attractiveness of the area as a whole." Indeed,

the economic regional progress is also linked to the tourism promotion and development, fostering each other in virtuous circle, since local/regional tourism uses local food or beverages both to enhance the tourism experience, and to support the tradition of local food/beverage production (Boyne et al., 2003).

On this basis, this study is focused on the detection of the potential of a product strictly linked to the territory, considering also that the area of origin of a product is a crucial characteristic for food products (Bryła, 2015). In this view, a role of territoriality is expected in the evaluation of the product, both from a subjective and from the visual behavior standpoints.

An important point is related to the fact that a large amount of literature on fish marketing has focused on Asian (e.g., Alam et al., 2010; Goon et al., 2012) and African markets (e.g., Abbott et al., 2015; Baba et al., 2015). In addition, much research reported greater visual attention to requests for the food origin (Van Loo et al., 2015; Drexler et al., 2018). To the best of our knowledge, the seafood marketing in Italy has never been addressed; in addition, the quantitative evaluation of the effectiveness of communication in the context of fish market in Sicily, and in general in Italy, is an unexplored field of research. More investigations in this direction could provide useful insights to companies operating in this sector and in the territoriality issues.

In these views, this study represents an additional contribution for both the literature and the applicative sides, considering a different market, such as the Italian one, contributing also in the European research in this area, bringing a contribution for the products and territorial promotions.

MATERIALS AND METHODS

Instrumentation

In order to obtain quantitative and qualitative data on visual paths (the series of fixations and saccades) and areas of interest (AOI) of the analyzed packaging, gaze data were recorded using the SMI-RED 250 eye-tracker bar (SensoMotoric Instruments GmbH) and the iView X (SensoMotoric Instruments GmbH) software, with a sample frequency of 250 Hz. iView X served also as a stimuli presentation tool. SMI-RED was attached to a 22" LCD monitor, with a pixel resolution of 1680 × 1050.

More in deep, AOI permits to define regions of a stimulus that the researcher is interested in gathering data about (Holmqvist and Andersson, 2017), and to link eye-movement measures to parts of the used stimulus. This study used AOI in order to measure Spent Time (the amount of time that consumers have spent looking at a particular AOI) and Entry Time (the time passed from the moment of the first fixation in a particular AOI) on brands and on products.

Sample and Procedures

The study involved 20 Italian university students with an average age of 23.9 (± 2.3), equally grouped for gender (10 males). The experimental station was placed in a laboratory room where the internal and external luminosity was controlled in order to standardize the environment in which the stimuli were displayed. Each subject sat on a chair placed in front of the 22" LCD monitor previously motioned. The distance between the subject and the monitor, as well as the angle of inclination between the subject's visual horizon and the eye tracker bar was controlled by the experimental operator. Once the control operations were complete, the operator started the calibration of the eye tracker. It consisted of a colored dot moving across the screen that the subject had to follow just with the gaze, keeping the head as still as possible. The recorded positions of both the dot and the subject's gaze serves to build the calibrated projection matrix, namely the mapping between the face and the monitor plane. Before presenting the experimental stimuli, the subject displayed a white sphere in the center of a black screen. The stimulus duration was about 60 s and was implemented in order to relax as much as possible once the calibration operation was finished and before the start of the experiment. During the 60 s the subject was asked to observe the white sphere and relax as much as possible.

After the preliminary calibration and baseline phase, subjects displayed the 24 stimuli. The subjects were explained that a series of images would be administered on the monitor and their task was to observe them freely. Each stimulus was consisting of the image of a single packaging, displayed for 6 s, in order to allow participants a comfortable observation of the packaging (Zhang and Seo, 2015).

In order to respect the with-in methodology of the research design, all participating subjects visualized all the stimuli, which were randomized between subjects. All the 24 stimuli have been presented in Italian. In order to collect data on the rational elaboration of the experience at the end of each visualized stimulus, three questions were proposed to the subjects. The nature of the questions and their evaluation scales will be discussed in more detail in the following paragraphs.

Packaging Stimuli

In order to optimize the collection of data without burdening the cognitive load of participants, 24 stimuli for packaging of fish products were selected from 12 Sicilian companies. The companies included in the research have been selected by the fisheries department of the Sicilian region "Dipartimento della pesca mediterranea dell'Assessorato regionale dell'agricoltura, dello sviluppo rurale e della pesca mediterranea" [*Department of Mediterranean Fisheries of the Regional Department of Agriculture, Rural Development and Mediterranean Fisheries*], which supported the present study. For each company two packaging were selected.

A further criterion for the selection of the stimuli concerned one of the fundamental drivers of the whole experiment: territoriality. Twelve stimuli presented clear references to the origin from Sicily of the displayed packaging, such as images of the island or texts referring to the place of origin of the product (see **Appendix** for examples). The products that had graphic and textual elements related to their territorial origin were not all part of the same brands. In order not to create a univocal association between the brand and the presence of territorial elements, half brands presented both a product with territorial connotation and a product without territorial connotation.

The selected packaging had very different characteristics both in terms of fish contained and in terms of shape and material.

This choice allowed us not to limit the study to specific types of packaging, but to conduct an analysis that included a wide range of characteristics from an exploratory point of view. The presence of references to Sicily therefore represents one of the major discriminating features of the whole research, as reported in the results.

Rational Evaluation

At the end of the visualization of each stimulus, the subject was asked to answer three questions to evaluate the experience. The three questions evaluated three different areas: perceived quality, economic evaluation of the product, willingness to pay. The three dimensions were asked in chronological order as previously presented. The perceived quality (Quality) was expressed on a Likert scale 1-7, whose extremes were represented by 1 = "very low quality"; 7 = "very high quality." The economic evaluation (Price) of the product and the willingness to pay (WTP) were investigated by asking subjects to select a price range. Both ranges of willingness to pay and estimated price, discretized within six categories, have been adapted to the product presented and its market price. More in dept, the six categories were the identified as the points of a price interval, created according to the minimum (MIN), maximum (MAX) and range (R = MAX – MIN) market prices of each product, provided by the fisheries department of the Sicilian region:

1. price < MIN
2. MIN < price < MIN + R/4
3. MIN + R/4 < price < MIN + R/2
4. MIN + R/2 < price < MAX – R/4
5. MAX – R/4 < price < MAX
6. price > MAX

The Quality was assessed trough the question "What is the quality of this product?", while Price and WTP were assessed trough "What is the economic value of this product?" and "How much would you be willing to pay for this product?," respectively.

The global means ± standard deviations of MIN, MAX, and R, expressed in €, were: MIN = 3.075 ± 3.957, MAX = 15.375 ± 19.787, R = 12.300 ± 15.830.

The collection of data on these three dimensions allowed to conduct correlations and statistical analysis between the emerged results and the metrics of visual and perceptual behavior extracted through the eye tracker tool.

TABLE 1 | Descriptive statistics of quality, price, and WTP in relation to territoriality.

	Territoriality	Mean	SD
Quality	N	3.733	1.655
	Y	4.729	1.584
Price	N	2.775	1.234
	Y	3.263	1.268
WTP	N	2.337	1.196
	Y	2.725	1.199

Y = presence of reference to territoriality on packaging; N = absence of reference to territoriality on packaging.

DATA ANALYSIS

The statistical analyses were performed using JASP 0.12.2 (JASP Team), an open-source R-based graphical software package (Love et al., 2019). In order to identify comparable sections in quantitative terms, the analysis of the Eye Tracker data has provided for the creation of three AOI on packaging. For all packaging, an area of interest on the brand and on the product name has been created. For packaging with characteristics related to territoriality (the Sicilian origin), an area has been created on the characterizing element. From each AOI two metrics have been extracted: Time Spent and Entry Time.

RESULTS

The results obtained from the questionnaire, eye tracker metrics (AOI metrics) and heatmaps (where spots indicate how many subjects were looking at the same time at a specific position) highlighted the importance of territoriality in the product evaluation and perception. Further insights underlined the gender difference in the packaging exploration and a relationships between the product name and the three dimensions detected in the questionnaire (Quality, WTP,

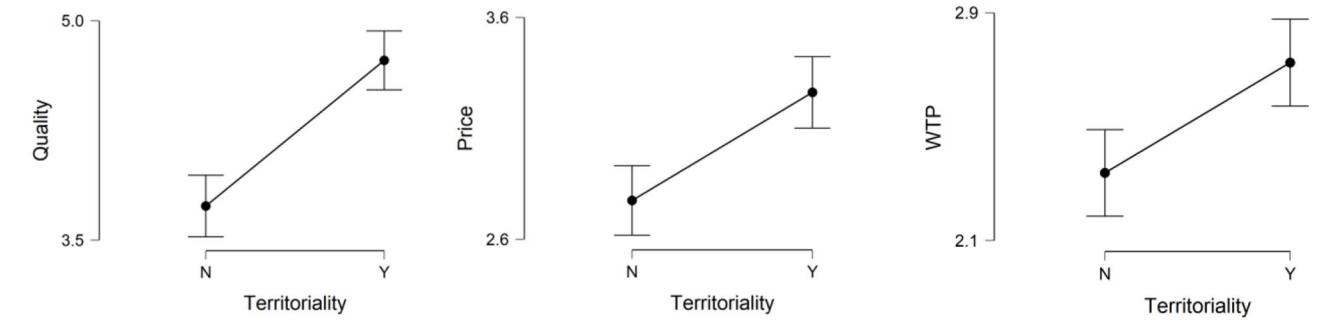

FIGURE 1 | Plot 1 – quality, price, and WTP /territoriality relation.

Price). All the results are discussed in more detail in the following paragraphs.

Effect of the Territoriality on Subjective Evaluation

The effect of territoriality on WTP, Quality and Price was assessed. Since the assumptions of normality (verified using the Shapiro-Wilk's test) and homoschedasticity (verified using the Levene's test) were not met, non-parametric Mann-Whinley's *U*-tests were performed. Additionally, the effect size was estimated by means of the Rank-Biserial Correlation coefficient r.

We found a significant and small-medium increases in Quality ($U = 19{,}733, p < 0.001, r = -0.315$) Price ($U = 22{,}680, p < 0.001$, $r = 0.212$) and WTP ($U = 23488.5$, $p < 0.001$, $r = -0.184$) for stimulus with territoriality.

Table 1 shows the descriptive statistics (mean and standard deviation) of the metrics and the following plots (**Figure 1**) show the means with the 95% confidence intervals.

All three dimensions of the questionnaire (Quality, WTP, Price) are statistically significant in relation to territoriality. In particular, all have a significantly higher average in those products that have elements of reference to Sicily. The results suggest how the presence of references to the territory influences the evaluation of the product, improving it when they are present.

Effect of the Territoriality on Eye Tracker Data

The effect of territoriality on Eye Tracker metrics was assessed. Since the assumptions of normality (verified using the Shapiro-Wilk's test) and homoschedasticity (verified using the Levene's test) were not met, non-parametric Mann-Whinley's *U*-tests were performed. Additionally, the effect size was estimated by means of the Rank-Biserial Correlation coefficient *r*.

We found significant and small increases in Product_TimeSpent ($U = 18451.5$, $p = 0.009$, $r = -0.148$) for stimulus with territoriality.

Table 2 shows the descriptive statistics (mean and standard deviation) of the metrics and the **Figure 2** contains the plot showing the mean with the 95% confidence intervals.

Eye Tracker Output on Territoriality

In order to appreciate the effective perception of territorial characteristics, the AOI metrics and heatmaps on packaging have been considered. The heatmaps shown in the **Appendix** are examples of the phenomenon on three of the analyzed products. The heatmaps were extracted from the BeGaze software of SMI (SensoMotoric Instruments GmbH). All the heatmaps confirm a similar phenomenon: the presence of elements evoking the Sicilian origin has a perceptive impact on the packaging's view. All the areas with clear references to Sicily are actually displayed. The phenomenon has therefore also been investigated at a quantitative level, through the percentage of Hit Ratio and average Time Spent of the overall sample. **Table 3** shows the average value of the AOI created in the areas of the territorial reference. It has to be noted that 75.6% of the sample actually displays the elements (Hit Rato). The average time spent on the area is about 593.6 ms (± 324.9). This data seems to confirm the results that emerged from the previously exposed data on the difference in Product_TimeSpent, Quality, WTP and Price averages. In addition to a significant difference, it is possible to suggest that this difference probably originates from the effective visualization of the territorial connotation.

TABLE 2 | Descriptive statistics of Product Time Spent in relation to territoriality.

	Territoriality	Mean	SD
Product_TimeSpent	N	1276.438	865.120
	Y	1525.543	979.288

Y = presence of reference to territoriality on packaging; N = absence of reference to territoriality on packaging.

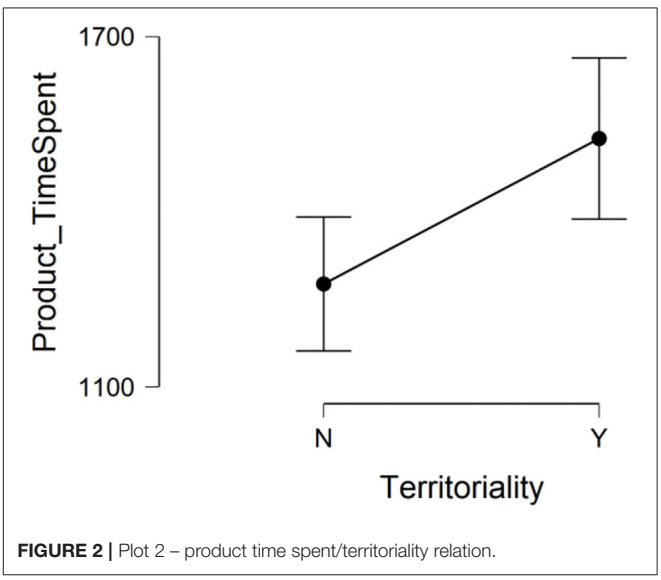

FIGURE 2 | Plot 2 – product time spent/territoriality relation.

TABLE 3 | Average value of AOI related to territoriality.

	AOI with references to territoriality (Overall Sample)
Time spent	593,5 ms
Hit ratio	75,60%

TABLE 4 | Descriptive statistics of Brand Time Spent, Brand Entry Time, Product Time Spent, and Product Entry Time in relation to gender.

	Group	Mean	SD
Brand_TimeSpent	F	1246.057	767.705
	M	919.933	720.270
Brand_EntryTime	F	845.623	979.168
	M	1572.285	1594.931
Product_TimeSpent	F	1533.048	872.921
	M	1237.710	964.063
Product_EntryTime	F	1039.887	978.423
	M	1314.530	1180.318

F = Female; M = Male.

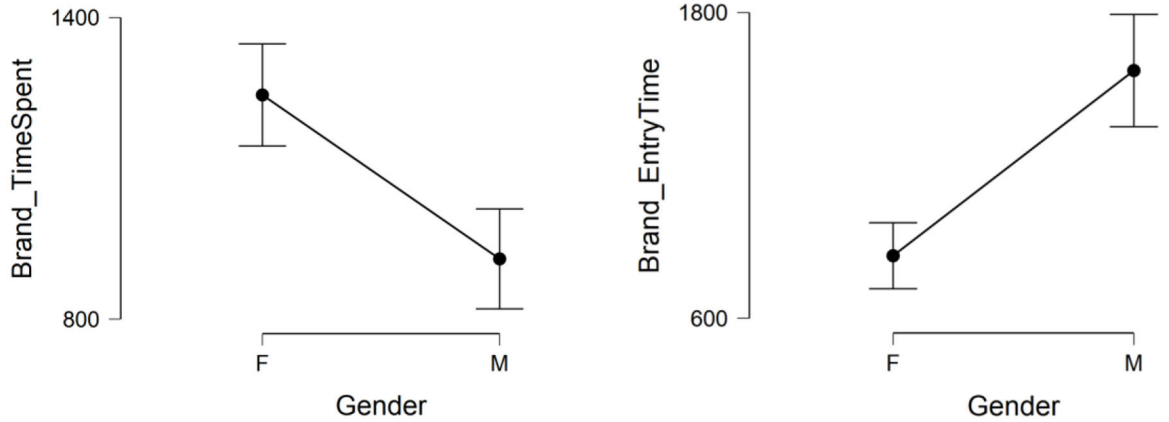

FIGURE 3 | Plot 3 – brand time spent, brand entry time/gender relation.

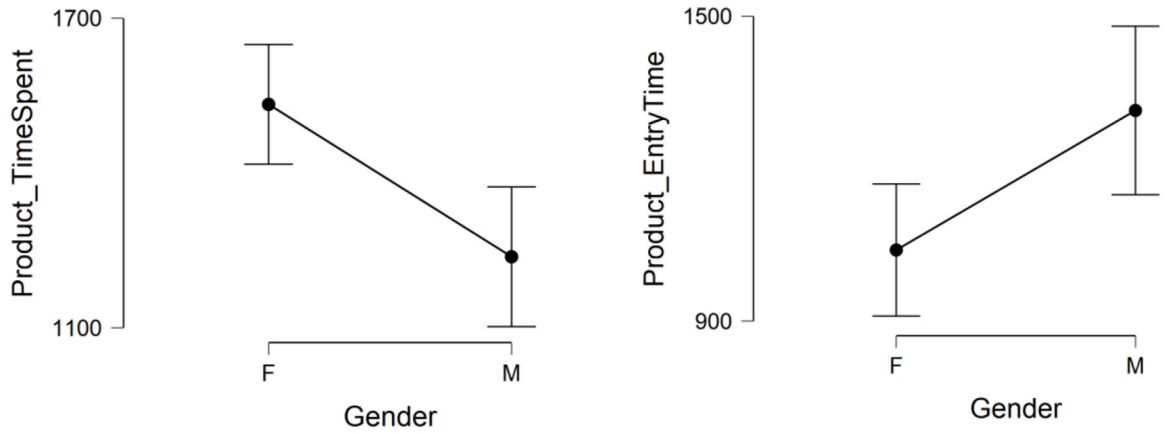

FIGURE 4 | Plot 4 – product time spent, product entry time/gender relation.

Effect of the Gender on Eye Tracker Data

In order to obtain a research that would cover as many drivers as possible in the optimization of fish communication, a possible gender difference in the exploration of stimuli was considered. Since the assumptions of normality (verified using the Shapiro-Wilk's test) and homoschedasticity (verified using the Levene's test) were not met, non-parametric Mann-Whinley's *U*-tests were performed. Additionally, the effect size was estimated by means of the Rank-Biserial Correlation coefficient r.

A small increase of Brand_TimeSpent ($W = 28779.5$, $p < 0.001$, $r = 0.0271$) and Product_TimeSpent ($W = 2{,}6625$, $p < 0.001$, $r = 0.229$) as well as a small decrease of Brand_EntryTimes ($W = 15929.5$, $p < 0.001$, $r = -0.297$) and Product_EntryTime ($W = 18592.5$, $p = 0.012$, $r = -0.142$) was found for the Females.

Table 4 shows the descriptive statistics (mean and standard deviation) of the metrics and the following plots (**Figures 3**, **4**) show the means with the 95% confidence intervals.

Effect of the Gender on Subjective Evaluation

The effect of the gender on WTP, Quality and Price was assessed. Since the assumptions of normality (verified using the Shapiro-Wilk's test) and homoschedasticity (verified using the Levene's test) were not met, non-parametric Mann-Whinley's *U*-tests were performed. Additionally, the effect size was estimated by means of the Rank-Biserial Correlation coefficient *r*.

No statistical difference was found for WTP, Quality, and Price between Males and Females.

Effect of Subjective Evaluation on Eye Tracker Metrics

Within an exploratory perspective, a relation between the Eye Tracker metrics and the data obtained from the three items of the questionnaire (Quality, WTP, Price) has been searched. Since the assumptions of normality of the residuals (verified by the Q-Q plot) and homoschedasticity (verified using the Levene's test) were not met, for each Eye Tracker metric, three non-parametric Kurskal-Wallis tests (one for each Subjective Evaluation) were performed, considering as factor, respectively, WTP (six levels) Quality (seven levels) and Price (six levels).

Significant effect of Quality on Product_TimeSpent was found ($\chi^2(6) = 24.846$, $p < 0.001$). Dunn's *post-hoc* comparison (Bonferroni-corrected) confirmed a significant difference between levels 1–4 ($z = -4.475$, $p < 0.001$), 1–5 ($z = -4.131$,

TABLE 5 | Descriptive statistics for the evaluation levels of the Quality dimension.

Quality	Mean	SD
1	755.937	504.910
2	1282.685	848.816
3	1233.767	806.552
4	1594.302	970.524
5	1527.717	981.541
6	1493.322	956.454
7	1415.748	1011.290

TABLE 6 | Descriptive statistics for the evaluation levels of the Price dimension.

Price	Mean	SD
1	1052.357	866.959
2	1208.583	778.633
3	1397.779	903.143
4	1593.933	947.039
5	1902.606	1132.705
6	1502.400	1109.201

TABLE 7 | Descriptive statistics for the evaluation levels of the WTP dimension.

WTP	Mean	SD
1	1163.142	804.263
2	1281.409	851.111
3	1517.974	982.546
4	1693.370	1061.087
5	1766.441	805.824
6	1168.888	1110.447

$p < 0.001$), 1–6 ($z = -3.746$, $p = 0.002$), and 1–7 ($z = -2.864$, $p = 0.044$).

Table 5 shows the descriptive statistics (mean and standard deviation) of each level.

Significant effect of Price on Product_TimeSpent was found ($\chi^2(5) = 22.655$, $p < 0.001$). Dunn's *post-hoc* comparison (Bonferroni-corrected) confirmed a significant difference between levels 1–4 ($z = -3.465$, $p = 0.004$), 1–5 ($z = -3.794$, $p = 0.001$), 2–4 ($z = -2.826$, $p = 0.035$), and 2–5 ($z = -3.215$, $p = 0.010$).

Table 6 shows the descriptive statistics (mean and standard deviation) of each level.

Significant effect of WTP on Product_TimeSpent was found ($\chi^2(5) = 17.449$, $p = 0.004$). Dunn's *post-hoc* comparison (Bonferroni-corrected) confirmed a significant difference between levels 1–4 ($z = -2.973$, $p = 0.022$).

Table 7 shows the descriptive statistics (mean and standard deviation) of each level.

The following figure with the plots (**Figure 5**) shows the means with the 95% confidence intervals.

The analysis seems to suggest a possible relationship between the time spent by consumers on the name of the product, the perceived quality, the willingness to pay and the estimated price on the market. In particular, a better overall perception of the product seems to be linked to a greater interest in the product's name.

Correlation Between Eye Tracker Metrics and Subjective Evaluation

A correlation analysis between Eye Tracker metrics, Subjective Evaluations, Gender and Territoriality was performed. Territoriality and Gender were codified respectively, as Y (Yes) =1; N (No) = 0, and as M (Male) =0; F (Female) =1. Since the assumption of bivariate normality (verified using the Shapiro-Wilk's Test) was not met, a non-parametric Spearman coefficient was computed.

Significant correlations were found for Price-Quality ($\rho_{(478)} = 0.646$, $p < 0.001$), WTP-Quality ($\rho_{(478)} = 0.649$, $p < 0.001$), WTP-Price ($\rho_{(478)} = 0.865$, $p < 0.001$), Brand_TimeSpent-Quality ($\rho_{(424)} = -0.148$, $p = 0.002$), Brand_TimeSpent-WTP ($\rho_{(424)} = -0.098$, $p < 0.042$), Brand_EntryTime-Quality ($\rho_{(424)} = 0.153$, $p = 0.002$), Brand_EntryTime-Brand_TimeSpent ($\rho_{(424)} = -0.427$, $p < 0.001$), Product_TimeSpent-Quality ($\rho_{(415)} = 0.157$, $p = 0.001$), Product_TimeSpent-Price ($\rho_{(415)} = 0.221$, $p < 0.001$), Product_TimeSpent-WTP ($\rho_{(415)} = 0.179$, $p < 0.001$), Product_TimeSpent-Brand_EntryTime ($\rho_{(375)} = -0.190$, $p < 0.001$), Product_EntryTime-Product_TimeSpent ($\rho_{(415)} = -0.202$, $p < 0.001$), Territoriality-Quality ($\rho_{(478)} = -0.277$, $p < 0.001$), Territoriality-Price ($\rho_{(478)} = -0.189$, $p < 0.001$), Territoriality-WTP ($\rho_{(478)} = 0.165$, $p < 0.001$), Territoriality-Brand_EntryTime ($\rho_{(424)} = 0.101$, $p = 0.038$), Territoriality-Product_TimeSpent ($\rho_{(415)} = 0.128$, $p = 0.009$), Gender-Brand_TimeSpent ($\rho_{(424)} = 0.234$, $p < 0.001$), Gender-Brand_EntryTime ($\rho_{(424)} = -0.257$, $p < 0.001$), Gender-Product_TimeSpent ($\rho_{(415)} = 0.198$, $p < 0.001$), and Gender-Product_EntryTime ($\rho_{(415)} = -0.123$, $p = 0.012$).

Figure 6 shows the heatmap of the correlation coefficients, with the related significances marked ($^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$).

DISCUSSION AND CONCLUSION

The purpose of this article was to investigate the way in which the communication of territoriality can influence the quality perception, the willingness to pay and the exploration of packaging.

This study is proposed as pioneering, for the used techniques, in the research and experimental study of the communication of fish products. The study of the visual behavior of consumers has allowed the correlation and analysis of strictly perceptual metrics such as those related to AOI on brand and product, with those resulting from the rational elaboration of the experience. The results of the drivers identified crucial points for the future communication of fish products and the promotion of the territory. In particular, the analysis lays the foundations for a reorganization of the approach to the creation of product packaging, through greater attention to detail and the intrinsic values that this can express. Among these, the importance

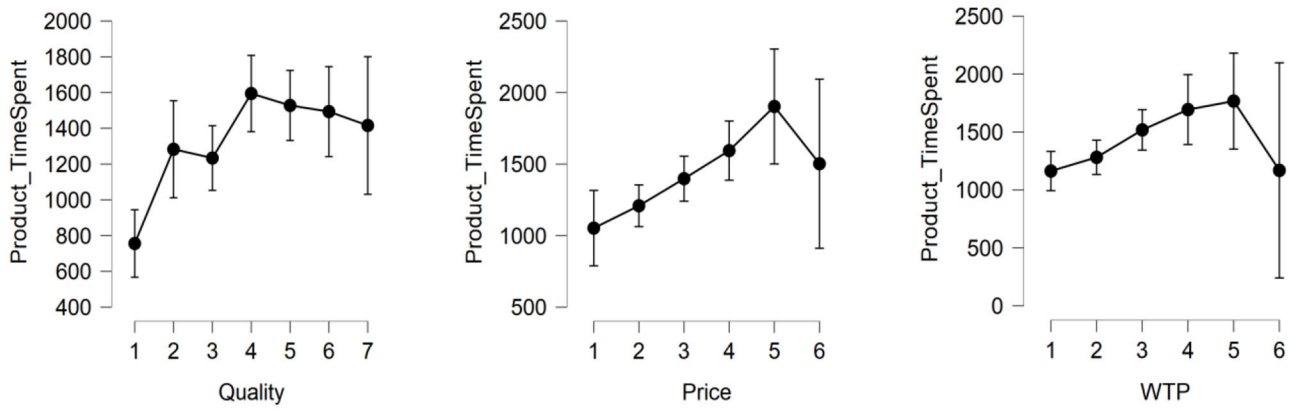

FIGURE 5 | Plots for the product time spent for quality, price, and WTP.

of territorial origin in the impact on product evaluation has been found.

As for the eye tracker data, the effect of territoriality on eye tracker metrics has been considered. Data suggests that an Eye Tracker variable seems to be linked to the territoriality. In actual fact, the time spent by participants on the product, named Product_TimeSpent is significantly higher in stimuli that have a territorial characterization. The attention paid to the name of the product and its characteristics seems to increase if there is a reference to the Sicilian origin. As shown in the correlation table (**Figure 6**) it is possible to consider other phenomena that need further study. The perceptive data on the brand, probably related to the more or less attractive characteristics of the fonts and their size, do not seem to be particularly relevant. Also the Product_EntryTime does not seem to be affected by the presence of territorial characterizations. Also in this case, the possible presence of other elements and characteristics could influence the non-significance of the data. In a pioneering study such as the one presented, these considerations represent the starting point for further investigation.

Moreover, to deepen the role of the territoriality, it has been detected through the consideration of AOI metrics and heatmaps on packaging. The analysis of the heatmaps and AOI of the elements characterizing the territory (the Sicilian origin) has highlighted how these are displayed, triggering the perceptive interest of consumers. In fact, all areas in the packaging with a clear reference to the territory of Sicily have been seen by the participants. These data are important evidence confirming the attractiveness of the regional origin of food products, that is increasing over the mass production (Domański and Bryła, 2013). Moreover, the visual impact of the elements characterizing the Sicilian origin is related to a greater interest in the product and its characteristics (Product_TimeSpent), as well as the perceived quality, the willingness to pay and the estimated price. Taking together, all these data are in line with studies suggesting that the area of origin is an important element when considering the food product (Bryła, 2015), and suggesting that, within different elements, territoriality and typicity are crucial elements of the origin of the products determining their credibility (van der Meulen, 2007).

In order to better assess the visual behavior to deepen the applicative side of fish communication, the study detected gender differences in visual attention while exploring packaging, showing some significant differences. In particular, females have a greater focus on the identity aspects of the product, the brand and the product name. The results showed that females actively seek this information more than male (Brand_EntryTime; Product_EntryTime) and pay more attention on it (Brand_TimeSpent; Product_TimeSpent). These differences in visual attention seem to be in line with a study by Darley and Smith (1995). Their study, indeed, showed that women are more sensitive to details and have a more complete visual processing of the stimulus. However, the differences found in visual attention did not show to have a significant effect on the self-report evaluations of the products.

As for correlation, the study has highlighted significant correlations on the role of the territory as a perceptive guide in the evaluation of the product. In fact, the territoriality variable is highly and positively associated with Quality, in line with studies suggesting that the region of origin of one product is an indicator of quality (Philippidis and Sanjuán, 2003). Moreover, territoriality shows positive correlations also with Price and WTP. These data are important since they are consistent with literature showing that the perception of the origin of a product and of quality are linked to the willing to pay a higher price for a product (Loureiro and McCluskey, 2000; Scarpa et al., 2005). Moreover, these data give further value to the importance of the composition and layout of the packaging of fish products, suggesting that the presence of the origin of a product, is a key factor for the product communication and attractiveness for consumers. Indeed, attention paid to the product name (Product_TimeSpent) has shown a high and positive correlation with Price, followed by other positive correlations with WTP, Quality and territoriality. This suggests that both information, territoriality and the name of the product, requires greater visibility on the label as it increases the value attributed to the

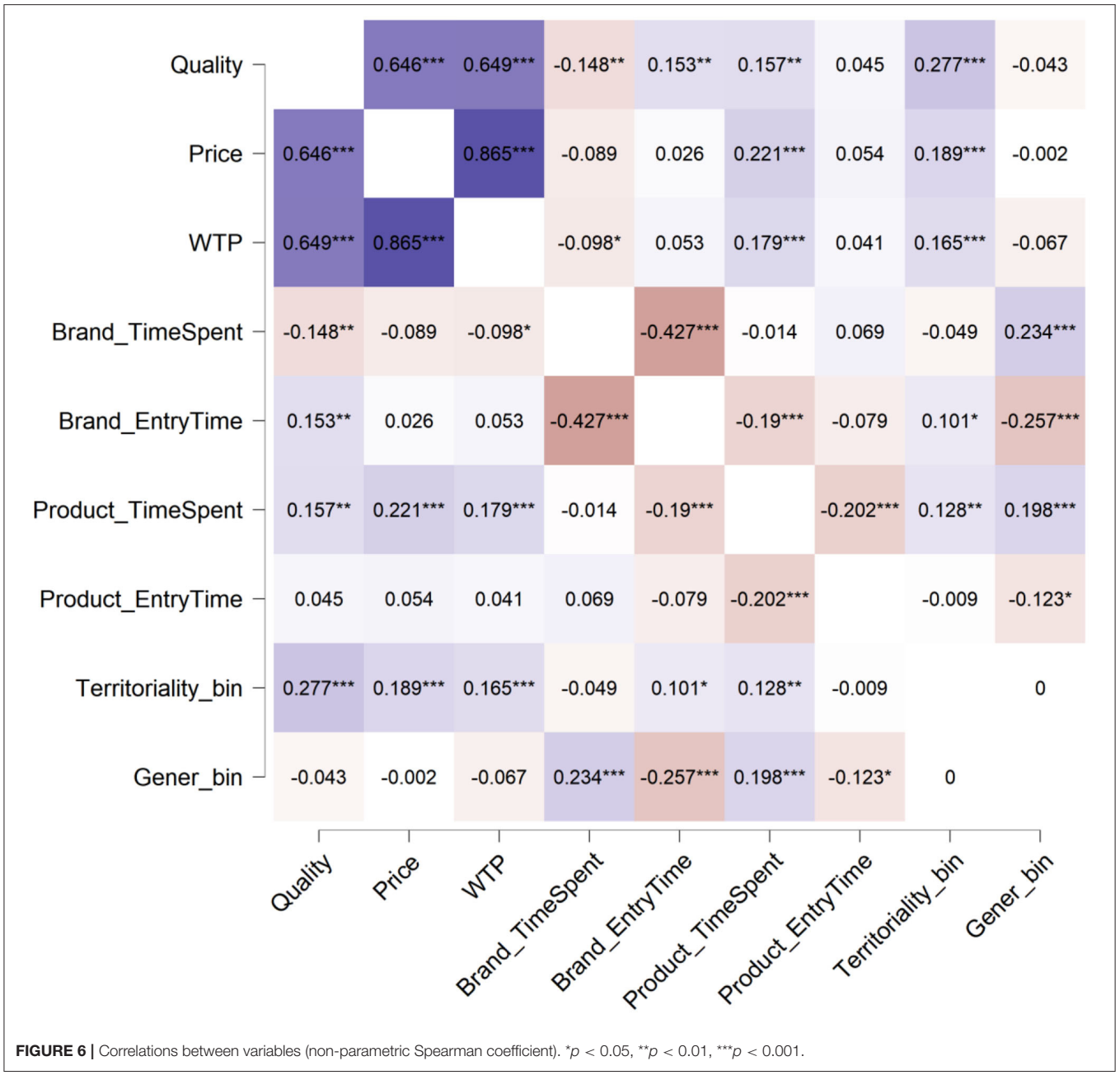

FIGURE 6 | Correlations between variables (non-parametric Spearman coefficient). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

product. The role of territoriality has been therefore confirmed in this study, as expected. Moreover, the same trend of previous analyses, was found in the analyses related to the subjective evaluation of Quality, Price and WTP in relation to territoriality. When stimulus showed the link to territoriality, that is the region of origin of the product, Quality, Price, and WTP were evaluated as higher, in particular as for Quality. This data is in line with the results of the analyses of the effect of subjective evaluation on eye tracker metrics. With reference to the Product_Time spent, Quality, and Price, indeed, showed significant effect particularly between the lowest levels of the evaluation scale and the highest, suggesting a possible relationship between the perceived quality and WTP and the estimated price with the time spent by consumers on the specific name of a product. This is a very interesting issue that has to be considered in the promotion and in the communication of a product. The possibility to attract the attention and to make the consumer engaged in spending time on a product name, with positive association with Quality and WTP, seems to be linked to the presence of the origin of the product. From an application point of view, this would represent an important key factor to promote a product a and its territory. For the specific Sicilian region, to which products and stimuli of this study are referred, adding the origin of a product could be the best solution for the fisheries regional market. It has

to be underlined that these important results can be useful for considering the role of territoriality also for other products and brand, in order to better communicate this as a value and to promote products and territories also among other categories.

This study, shows an innovative perspective based not only on the subjective evaluation by consumers on the product and its characteristics. In fact, the use of neuromarketing techniques has proved valid in identifying what is the main information that is processed for the evaluation of the product. Neuroscience techniques, indeed, give an added value that is the possibility to study the processing of information considering the role played by emotions (Passyn and Sujan, 2006). According to studies on consumers behaviors and decision processes, measurements based on the registration of neuro-physiological parameters, could give an accurate and reliable results due to the fact that lacks the mediation of the cognitive processes (Poels and DeWitte, 2006; Missaglia et al., 2017). Neuroscience applied to marketing issues, indeed, has the aim to discover what is happening in the brain in response of some stimuli from products, brain or advertising to discover which strategy lead to the buying process. This study used one of the main tool used in neuromarketing, that is the eye tracker, giving a new perspective through a neuroscientific approach. The importance of Neuromarketing techniques in assessing the perceptive and emotional experience of consumers when approaching the product could be a key asset for the consumption of fish products in the future.

For this reason, a limitation of this study is represented by the use of a unique neuromarketing tools. Future studies should focus also on the neuro and psychophysiological signals, in order to measure the consumers' emotional reaction to products, that is a spontaneous aspect of emotional reaction in real time, and to investigate communication strategies focused on food packaging (Russo et al., 2020a). Moreover, future studies should verify the effect of cross-media exposure in the communication strategy, which could help in the detection of the most effect of combination on media, improving the communication performance (Russo et al., 2020b). This aspect would be very functional and helpful to deepen the relationship between the territoriality and the exposure to the product.

Another limitation of this study is the use of a small group of participants. Within neuromarketing literature, this is not a very small sample, but it could be enlarged in order to have more generalizable data, read in the light of a different source of knowledge (Ferguson et al., 2014). Moreover, future studies could consider also a specific sample composed by regular fish consumers, in order to better capture their attitude and behavior toward this specific packaging and territoriality characteristics. For this reason, this research can be considered a first exploratory and pilot study for the detection of fish consumers behaviors, a model which can be also extended to other products, brand and territories.

However, this study highlights a specific element, the territoriality, to optimize the communication of fish products in a circular and continuously improving vision. In addition, further analysis may be conducted on the role of some variables and the correlations highlighted. The study, although it had a clear initial hypothesis, highlighted further phenomena that could be investigated later, opening a new line of research.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the IULM University. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MZ, LM, and VR designed the research. AF, RC, FR, and MBi collected the data and carried out data analysis and interpretation. MZ, AF, RC, MBi, and VR wrote the manuscript. FR, MBe, and VR edited the final version. VR, LM, RC, and MZ supervised the project and the paper writing. All authors contributed to the present study and the final version of the manuscript has been approved for submission by all authors: they are accountable for the whole work.

FUNDING

This study was supported by the section of Sicily region Dipartimento della pesca mediterranea dell'Assessorato regionale dell'agricoltura, dello sviluppo rurale e della pesca mediterranea [Department of Mediterranean Fisheries of the Regional Department of Agriculture, Rural Development and Mediterranean Fisheries] and Survey for the enhancement of Sicilian fish products and consumption behaviors: Analysis of the dynamics of promotion and marketing of the Sicilian fish product, protocol code D.D.G 532/fishing, 27/10/17.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2021.659484/full#supplementary-material

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

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frontiers in Psychology

ORIGINAL RESEARCH
published: 20 April 2021
doi: 10.3389/fpsyg.2021.648871

Electrophysiological Correlates of Processing Warning Signs With Different Background Colors: An Event-Related Potentials Investigation

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: 12 January 2021
Accepted: 26 March 2021
Published: 20 April 2021

Citation:
Yuan J, Song Z, Hu Y, Fu H, Liu X and Bian J (2021) Electrophysiological Correlates of Processing Warning Signs With Different Background Colors: An Event-Related Potentials Investigation. Front. Psychol. 12:648871. doi: 10.3389/fpsyg.2021.648871

Warning signs, as a type of safety signs, are widely applied in our daily lives to informing people about potential hazards and prompting safe behavior. Although previous studies have paid attention to the color of warning signs, they are mostly based on surveys and behavioral experiments. The neural substrates underlying the perception of warning signs with different background colors remain not clearly characterized. Therefore, this research is intended to address this gap with event-related potentials (ERPs) technique. Warning signs with three different background colors (i.e., white, yellow, and blue) were used in the experiment. The results showed that the perceptual differences between different warning signs were present in the form of differential ERPs components (P1, N1, P2, N2, and P3) though subjects were not required to explicitly attend to the warning signs.

Keywords: warning signs, background color, hazard perception, event-related potentials, safety signs

INTRODUCTION

Colors are widely used in our daily lives and play important roles other than simple decoration. They not only help people to distinguish different objects but also convey messages. For example, in general, a red traffic light means "stop," a green traffic light means "go," and a yellow traffic light means "take caution." In the Chinese stock market, red color signals the rise in stock price, while green signals the fall of stock price. Yet in America, the meanings of colors in the stock market are opposite to those in China. Therefore, different colors are perceived differently, depending on the context where they are used. Given that colors are capable of conveying hazard or risk information intuitively, they are considered as a main design element of safety signs (Edworthy and Adams, 1996; ANSI, 2007; GB2894, 2008).

As a type of safety sign, warning sign is a prominent tool used to remind people of potential hazards and instruct them to behave safely. A lot of effort has been devoted to the design and effectiveness of warning signs in the past decades (Chan and Ng, 2010; Ma et al., 2010, 2018; Chan and Ng, 2012; Bian et al., 2020; Zhu et al., 2020). In this research trend,

the color of warning signs has also received considerable attention because color is essential when the textual message is restricted (Chapanis, 1994; Braun et al., 1995; Borade et al., 2008; Siu et al., 2017; Chen et al., 2020). White, yellow, orange, and red colors are found to be associated with successively greater perceived hazard levels (Chapanis, 1994). Colored warning labels are regarded as more readable and more hazardous than black-and-white warning labels (Braun et al., 1995). Braun and Shaver (1999) studied warning signs with different colors behind the signal word (red vs. blue) and different levels of text explicitness (none vs. low vs. high), and noted that red warnings resulted in higher hazard ratings than blue warnings only when the text explicitness was high. Luximon et al. (2003) suggested that warning signs with red background, black border, and white text led to the highest danger rating, while white background, blue border, and black text led to the highest information rating. A recent study revealed that red warning signs were easier to be identified and understood than yellow and black signs (Chen et al., 2018). Based on the Indian population, Borade et al. (2008) demonstrated that certain colors signaled different hazard levels and suggested that population factors be considered in hazard communication. Moreover, it is indicated that a fire safety evacuation sign with "green and black" color leads to the lowest cognitive load, highest search efficiency, and best evacuation escape performance (Chen et al., 2020).

Drawing from extant literature on sign colors, it could be seen that the findings are mixed and more research is needed to figure out which color is most effective for warning signs to communicate hazard information. Meanwhile, since prior studies on sign colors mainly adopted interviews, surveys, and behavioral experiments (Wogalter and Laughery, 1996; Rogers et al., 2000; Laughery, 2006; Williams and Noyes, 2007), relatively little is known about the neural correlates of how people perceive warning signs with different colors. Therefore, this research took a preliminary step and focused on exploring the neural processes underlying the perception and cognition of warning signs with different background colors with event-related potentials (ERPs) technology.

Event-related potentials provide direct measures of perceptual and cognitive processes with high temporal resolution. Amplitudes of ERPs components are supposed to represent the degree of engagement of cognitive processes, and latencies of them indicate the time stages of information processing (Luck, 2005). Among ERPs components, P1, N1, and P2 are considered to index relatively early perceptual stages of information processing, while N2 and P3 (including P300 and LPP) are considered to index relatively late, elaborate and high-level cognitive process, with P and N indicating whether a component is positive-going or negative-going and the number indicating a component's ordinal position within the waveform (Thomas et al., 2007; Lu et al., 2010). P1 typically arises at about 100 ms after stimulus onset and is associated with the physical features of the stimulus (Vogel and Luck, 2000; Zhao, 2010; Kendall et al., 2016). A Stimulus with high contrast and reduced complexity evokes smaller P1 amplitude than a stimulus with low contrast and increased complexity (Hosseinmenni et al., 2015; Kendall et al., 2016). Also sensitive to the visual features, N1 indicates the discrimination and classification of stimuli (Eimer, 2000; Vogel and Luck, 2000). For instance, the discrimination between facial and non-facial stimuli and between stimuli with different emotional valence is found to induce pronounced N1 component (Eimer, 2000; Frühholz et al., 2011). Frontal P2 is related to attentional processing and working memory manipulations (Holmes et al., 2008; Lu et al., 2010). A larger P2 amplitude is found to be evoked by objects with appropriate color than those with inappropriate color, suggesting that the perceptual memory about natural color is activated during the relatively early stage of information processing (Lu et al., 2010). Frontal N2 has been reported to be indicative of stimulus classification (Cao et al., 2010; Lu et al., 2010; Nittono et al., 2010). Moreover, P3 reflects attention allocation related to stimulus evaluation and categorical processing (Polich, 2007; Holmes et al., 2008). Categorization of stimuli along evaluative or non-evaluative dimensions has been revealed to be associated with P3 component (Cao et al., 2010; Fu et al., 2017).

Prior research has shown that ERPs are conducive to understanding how people process safety signs (Fu et al., 2017; Ma et al., 2018; Lu and Hou, 2019; Bian et al., 2020; Zhu et al., 2020). For instance, warning signs with higher hazard levels are associated with increased N1, N2, and P300/LPP components (Ma et al., 2010, 2018; Fu et al., 2017; Bian et al., 2020), and a reduced P2 component (Ma et al., 2018; Bian et al., 2020). In addition, ERPs have also been employed to study the cognitive processing of different colors (Holmes et al., 2008; Cano et al., 2009; Cao et al., 2010; Lu et al., 2010). For example, Cao et al. (2010) explored how people process yellow and blue colors and noticed that larger N1, P2, N2, and P3 components were evoked by yellow (vs. blue) stimulus. Cano et al. (2009) reported that affective valence had an effect on P3 component when the image was in color, but did not when the image was in black-and-white. Color knowledge affects early object recognition stages, such that N1, P2, and N2 components differ between objects in their appropriate colors and objects in inappropriate colors (Lu et al., 2010).

In this study, we attempts to extend previous studies on warning signs by investigating how people perceive warning signs with different background colors with an implicit paradigm. Recent research suggests that an implicit paradigm that does not require participants to explicitly pay attention to the safety signs is feasible to study how people perceive these signs, since they might be processed implicitly in many real life cases (Ma et al., 2018; Bian et al., 2020). Such a paradigm is not only helpful in examining the automatic information processing driven by stimuli, but also in avoiding a "relevance-for-task" effect (Bian et al., 2020; Zhu et al., 2020). Accordingly, the electroencephalogram (EEG) experiment in the present study adopted an implicit paradigm. A questionnaire-based experiment was performed in advance to collect subjective data, which provided an important complement to the EEG data. Neurophysiologically, we expect that warning signs with different background colors will lead to differential perceptual (P1, N1, and P2) and cognitive (N2 and P3) ERPs.

MATERIALS AND METHODS

Subjects

Eighteen subjects (six females) aged between 19 and 34 years (M ± SD = 23.06 ± 4.29) were recruited from Zhejiang University as paid volunteers. All subjects were healthy, right-handed native speakers with normal or corrected-to-normal vision. Meanwhile, they reported to be free of any history of neurological disorders and mental diseases. The protocol of this study complied with Declaration of Helsinki and was approved by the Internal Review Board of the Neuromanagement Lab in Zhejiang University. Each participant provided a written informed consent before the formal experiment started. Data from one male subject was discarded due to excessive recording artifacts, leading to 17 valid subjects (six females) for final analysis.

Materials

This study attempted to examine the implicit processing of warning signs with three different background colors (i.e., white, blue, and yellow). Twelve pictures of warning signs with yellow background were selected according to the Chinese National Standard for safety signs (GB2894, 2008). Adobe Photoshop CS3 image processing software (Adobe Systems Incorporated, San Jose, California, United States) was used to alter the background color of these signs. Hence three groups of warning signs were obtained with different background colors but identical pictorials and surrounding shapes (see **Figure 1** as an example). Accordingly, three main conditions were created, i.e., warning signs with white, blue and yellow backgrounds (hereafter also referred to as white, blue and yellow signs). The quality, size and resolution of pictures remained consistent across conditions. A questionnaire-based experiment was conducted to collect self-report data on people's perception of these signs. One hundred and twenty-four respondents who did not participate in the EEG experiment were randomly assigned to one of the three conditions. They were asked to rate the perceived hazard level and readability of each sign on seven-point Likert scales (1 = very low, 7 = very high; Braun et al., 1995). The respondents were also required to indicate the background color of warning signs in the Chinese national standard and to indicate which background color was most feasible for warning signs in their opinion.

In the EEG experiment, however, warning signs were used as non-target stimuli and subjects were not asked to attend to the signs. Twelve neutral pictures of chairs were selected as target stimuli and subjects were required to count the number of chairs presented in each block. During the experiment, each picture was repeated three times. Therefore, there were 144 trials in total, with 36 trials in each condition (i.e., white signs, blue signs, yellow signs, and chairs).

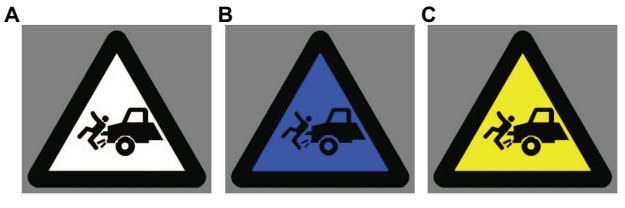

FIGURE 1 | Examples of experimental stimuli. A warning sign with **(A)** white, **(B)** blue, and **(C)** yellow background.

Procedure

The experimental procedure was similar to the study conducted by Bian et al. (2020). Subjects were seated comfortably in a dimly lit, sound-attenuated and electrically shielded room with the computer screen positioned approximately 100 cm in front of them. The experimental procedure was introduced on paper handouts prior to the formal experiment. Subjects were informed that they would be shown a number of stimuli in each block and the experiment was intended to assess their accuracy in memorizing the number of target stimuli. They were also told that the payments for their participation were linked to their performances in the experiment. Each subject had a practice session with 10 trials to get familiar with the experimental procedure.

Subjects had to complete three blocks in the formal experiment, with 48 pseudorandomized trials in each block. The stimuli were presented at the center of a gray screen. As **Figure 2** displayed, each trial began with a cross presented for 200 ms, following that was an interval with a random duration between 400 and 600 ms. Then, a target or non-target stimulus was presented for 800 ms, which was followed by an inter-trial interval lasting for 1,200 ms. Subjects were required to count the number of target stimulus (chairs) in each block in their minds and to report the number upon completion of the block. By this mean, subjects were prompted to focus their attention on the target stimuli, rendering the processing of warning signs task-irrelevant (Ma et al., 2018; Bian et al., 2020; Zhu et al., 2020). Data from a subject would be excluded from final analysis if he (or she) got the numbers wrong in more than one block. In fact, no subjects made mistakes in two or more blocks. Hence, the performance of all subjects was deemed to be acceptable and each of them was paid for 30 RMB as a financial reward at the end of the experiment.

Electroencephalogram Data Acquisition and Analysis

Scalp EEG was recorded continuously with an electrode cap with 64 Ag/AgCl electrodes mounted according to the extended international 10–20 system. Data were sampled at 1,000 Hz using Neuroscan Synamp2 Amplifer (Scan 4.3.1, Neurosoft Labs, Inc. Sterling, United States), with online band-pass-filtered from 0.05 to 100 Hz. Electrooculogram (EOG) was recorded from electrodes placed 1.0 cm lateral to the external canthi of both eyes (horizontal EOG), and above and below the left eye (vertical EOG). A cephalic location was applied as the ground and the left mastoid served as on-line reference. Impedances were kept below 5 KΩ throughout the experiment.

During off-line processing, channel data were re-referenced to the average of the left and right mastoids and corrected

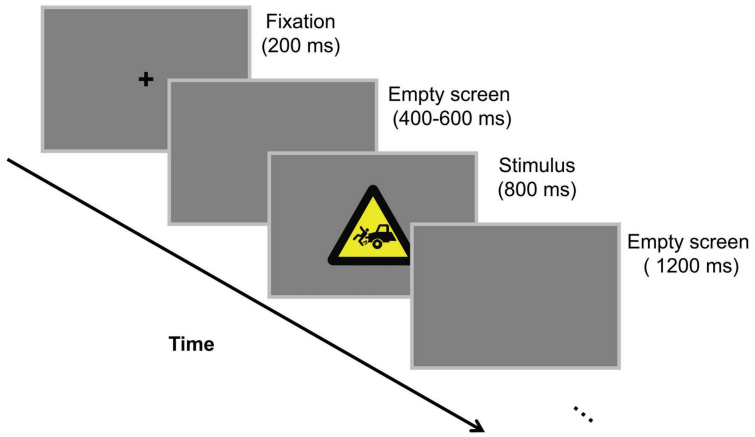

FIGURE 2 | Experimental scheme. Subjects were asked to count the number of chairs presented in each block in their mind.

for excessive eye movement using the Semlitsch et al. (1986) procedure. Stimulus-locked EEG data were digitally filtered with a bandpass from 0.1 to 30 Hz (24 dB/Octave) and segmented into epochs comprised of 200 ms before stimulus onset and 800 ms after the onset. Afterward, data were baseline-corrected by the 200 ms pre-stimulus interval. Trials contaminated by amplifier clipping, bursts of electromyographic activity, or peak-to-peak deflection exceeding ±80 μV were excluded from averaging. Only non-target stimuli (warning signs) were analyzed in this study. Therefore, EEGs over each recording site were averaged for white, blue, and yellow signs separately for each subject. These data were then grand averaged for each condition.

Based on visual inspection of the grand averaged waveforms and prior research on safety sign and color perception, five components of ERPs, P1, N1, P2, N2, and P3, were quantified from the individual participants' waveforms. Eight electrodes (P7, P8, PO7, PO8, CB1, CB2, O1, and O2) in the parietal and occipital regions were selected for P1 and N1 analyses. Six electrodes (F3, Fz, F4, FC3, FCz, and FC4) in the frontal and fronto-central regions were selected for P2, N2, and P300 analyses. The mean amplitudes in the time windows of 100–120 and 150–170 ms were computed for P1 and N1, respectively, before being submitted to 3 (color: white, blue, and yellow) × 8 (electrode: P7, P8, PO7, PO8, CB1, CB2, O1, and O2) repeated measure ANOVAs. Similarly, the mean amplitudes in the time windows of 145–165, 215–245, and 350–380 ms were calculated for P2, N2, and P300, respectively, before entering 3 (color: white, blue, and yellow) × 6 (electrode: F3, Fz, F4, FC3, FCz, and FC4) repeated measure ANOVAs. The Greenhouse–Geisser correction was applied in case of violation of the sphericity assumption and the Bonferroni correction was used for multiple paired comparisons.

RESULTS

Self-Repot Results

Among the 124 respondents who took part in the questionnaire-based experiment, 57.3% of them were female and 42.7% were male, with age ranges of 18–25 (25.8%), 26–30 (24.2%), 31–40 (33.1%), 41–50 (12.1%), and larger than 50 (4.8%). The ANOVAs on perceived hazard level [$F(2,121) = 4.523$, $p = 0.013$, $\eta^2_p = 0.070$] and readability [$F(2,121) = 4.731$, $p = 0.011$, $\eta^2_p = 0.073$] showed significant main effects of color. As illustrated in **Table 1**, pairwise comparisons showed that yellow and white signs were perceived to be associated with higher level of hazard and to be more readable than blue signs. Seventy-nine percent of the respondents correctly indicate that yellow was the background color for warning signs in the Chinese national standard, while 11.3% of them thought that white was the one and 9.7% of them thought blue was the one. Moreover, the percentage of the respondents that indicated yellow as the most feasible background color for warning signs was 79.8%, while the percentages for white and blue were 11.35 and 8.9%, respectively.

ERPs Results

P1 Analysis

The ERPs grand averaged waveforms at two representative clusters (parietal-and-occipital cluster and frontal cluster) are displayed in **Figure 3**. The ANOVA on P1 amplitude showed that the main effect of color [$F(2,32) = 5.874$, $p = 0.014$, $\eta^2_p = 0.269$] was significant. As illustrated in **Table 2**, the amplitude of P1 component induced by blue signs ($M = 3.493$ μV, S.E. = 0.472) was larger than that induced by yellow signs ($M = 2.596$ μV, S.E. = 0.416, $p = 0.033$) and white signs ($M = 2.311$ μV, S.E. = 0.448, $p = 0.057$). But there was no significant difference in P1 amplitude between the yellow and white signs ($p = 1.000$). The main effect of electrode was significant [$F(7,112) = 3.859$, $p = 0.033$, $\eta^2_p = 0.194$], but the interaction between color and electrode was not [$F(14,224) = 1.451$, $p = 0.225$, $\eta^2_p = 0.083$].

N1 Analysis

The ANOVA on N1 amplitude indicated a significant main effect of color [$F(2,32) = 5.566$ μV, $p = 0.008$, $\eta^2_p = 0.258$].

TABLE 1 | Summary of self-report results.

	white		blue		yellow		Pairwise comparison results
	M	S.E.	M	S.E.	M	S.E.	
hazard level	5.815	0.122	5.442	0.119	5.935	0.124	yellow > blue*, white > blue˙
readability	5.634	0.157	5.112	0.153	5.665	0.147	yellow > blue*, white > blue*

˙$p < 0.1$; *$p < 0.05$.

Blue signs (M = 0.132 μV, S.E. = 0.805) led to a smaller N1 than yellow signs (M = −0.734 μV, S.E. = 0.804, p = 0.065) and white signs (M = −0.814 μV, S.E. = 0.778, p = 0.034). But there was no significant difference between yellow and white signs (p = 1.000). Moreover, the main effect of electrode [$F(7,112) = 0.600$, p = 0.627, η^2_p = 0.036] and the interaction between color and electrode [$F(14,224) = 1.672$, p = 0.196, η^2_p = 0.095] were not significant.

P2 Analysis

The results showed that the main effect of color [$F(2,32) = 5.162$, p = 0.01, η^2_p = 0.244] was significant. Yellow signs (M = 4.595 μV, S.E. = 0.947) evoked a larger P2 than blue signs (M = 3.400 μV, S.E. = 0.806, p = 0.071) and white signs (M = 3.295 μV, S.E. = 0.771, p = 0.020). But there was no significant difference between the blue and white signs (p = 1.000). The main effect of electrode [$F(5,80) = 2.340$, p = 0.094, η^2_p = 0.128] and the interaction between color and electrode [$F(10,160) = 0.813$, p = 0.517, η^2_p = 0.0458] were not significant.

N2 Analysis

The ANOVA on N2 amplitude revealed a significant main effect of color [$F(2,32) = 5.447$ μV, p = 0.009, η^2_p = 0.254]. White signs (M = −2.132 μV, S.E. = 0.972) elicited a more negative N2 amplitude than yellow signs (M = −0.342 μV, S.E. = 0.858, p = 0.050) and blue signs (M = −0.543 μV, S.E. = 0.790, p = 0.048). But N2 did not differentiate between yellow and blue signs (p = 1.000). The main effect of electrode [$F(5,80) = 9.733$, p = 0.000, η^2_p = 0.378] and the interaction between color and electrode [$F(10,160) = 2.211$, p = 0.020, η^2_p = 0.121] were significant. Follow-up simple contrasts indicated that the simple main effects of color were significant for electrodes in the left (F3 and FC3, $ps < 0.05$) and middle regions (FZ and FCZ, $ps < 0.05$), but not for those in the right region (F4 and FC4, $ps > 0.1$).

P3 Analysis

The results showed that the main effect of color was significant [$F(2,32) = 3.498$, p = 0.042, η^2_p = 0.179]. Planned contrast indicated that yellow signs (M = 4.798 μV, S.E. = 1.237) induced a larger P3 than white signs (M = 3.258 μV, S.E. = 1.356, p = 0.007). However, P3 did not differ between yellow and blue signs (M = 3.887 μV, S.E. = 1.423, p = 0.587) and between blue and white signs (p = 0.985). The main effect of electrode [$F(5,80) = 7.087$, p = 0.001, η^2_p = 0.307] was significant. But the interaction between color and electrode was not significant [$F(10,160) = 0.891$, p = 0.543, η^2_p = 0.053].

DISCUSSION

Color, as an indispensable visible feature of safety signs, captures people's attention easily and plays an important role in conveying information about potential hazards (Edworthy and Adams, 1996). Though prior research has endeavored to understand the effect of color on hazard perception, relatively little is known about how people perceive warning signs with different background colors in the brain. Consequently, this study is intended to delve into the neural substrates of the perception and cognition of warning signs with different background colors by electrophysiological technique. Meanwhile, an implicit paradigm, which did not require explicit attention toward warning signs was adopted to avoid a "relevance-for-task" effect (Yuan et al., 2007; Ma et al., 2018; Bian et al., 2020; Zhu et al., 2020).

Are Perceptual and Cognitive ERPs Sensitive to Sign Color?

The ERPs results showed that both perceptual components (P1, N1, and P2) and cognitive components (N2 and P3) were evoked by warning signs with different background colors. P1 and N1 components were mainly observed in the parietal and occipital scalp regions, while P2, N2, and P3 were observed in the frontal and fronto-central regions. In general, perceptual components are indicative of earlier, lower-level and more automatic and exogenous stages of information processing and cognitive components more controlled, elaborate, and conscious cerebral activities (Thomas et al., 2007; Lu et al., 2010).

As an early attention-related perceptual component, P1 typically appears at about 100 ms after stimulus onset and is closely related to the visual features of the stimulus (Zhao, 2010; Hosseinmenni et al., 2015). P1 is sensitive to the clear and ambiguous features contained by a stimulus. For example, a smaller P1 amplitude is found to be elicited by a stimulus with high contrast and low complexity than a stimulus with low contrast and high complexity (Hosseinmenni et al., 2015; Kendall et al., 2016). In this study, compared to warning signs with blue background, those with yellow and white backgrounds resulted in decreased P1 amplitudes. This finding may be due to the fact that warning signs with different background colors differ in low-level features (e.g., visual contrast). Given their visual features, warning signs with yellow and white backgrounds are easier to be recognized than signs with blue background. The self-report results also support this notion, as respondents indicated that warning signs with yellow and white backgrounds were more readable than those with blue background.

Similar to P1 component, N1 is liable to be affected by physical features of stimuli (Hillyard and Anllo-Vento, 1998; Luck, 2005; Niu et al., 2008). N1 in the parietal and occipital scalp regions reflects discrimination and classification of stimuli. For example, as proposed by Vogel and Luck (2000), N1 induced by visual stimuli indicates the classification of stimuli at the

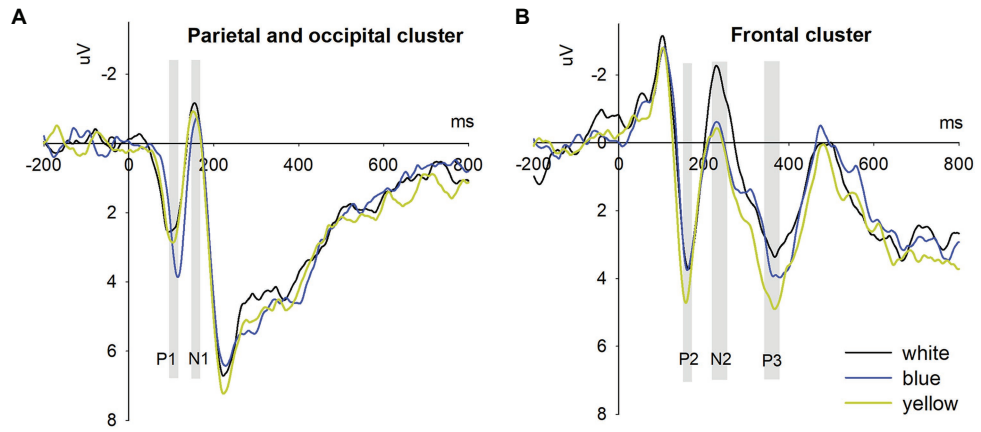

FIGURE 3 | Event-related potentials results. **(A)** The parietal-and-occipital cluster represents the averaged waveforms across eight electrodes (P7, P8, PO7, PO8, CB1, CB2, O1, and O2); **(B)** The frontal cluster represents the averaged waveforms across six electrodes (F3, Fz, F4, FC3, FCz, and FC4).

TABLE 2 | Summary of event-related potentials (ERPs) results.

	white		blue		yellow		Pairwise comparison results
	M (μV)	S.E.	M (μV)	S.E.	M (μV)	S.E.	
P1	2.311	0.448	3.493	0.472	2.596	0.416	yellow < blue*, white < blue˙
N1	−0.814	0.778	0.132	0.805	−0.734	0.804	yellow > blue˙, white > blue*
P2	3.295	0.771	3.400	0.806	4.595	0.947	yellow > blue˙, yellow > white*
N2	−2.132	0.972	−0.543	0.790	−0.342	0.858	white > blue*, white > yellow*
P3	3.258	1.356	3.887	1.423	4.798	1.237	yellow > white**

*P1, P2, and P3 refer to the first, second, and third positive components after stimulus onset, N1 and N2 refer to the first and second negative components after stimulus onset. ˙p < 0.1; *p < 0.05; **p < 0.01. The relative magnitudes of an ERPs component in different conditions were determined depending on its polarity.*

early stage of attentional processing. Additionally, a number of studies have linked N1 to the discrimination between facial and non-facial stimuli (Eimer, 2000) and the detection of the emotional valence of the stimuli (Frühholz et al., 2011). A more negative N1 amplitude is deemed to be associated with more attention devoted to the stimuli. In the present study, warning signs with yellow and white backgrounds led to larger N1 component than those with blue background, indicating that yellow and white signs attracted more attention from subjects and were more likely to be distinguished from blue signs.

P2 in frontal region belongs to the early stage of perceptual processing and is related to the allocation of attention resources and working memory manipulations (Holmes et al., 2008; Lu et al., 2010). The natural color of objects (such as red for strawberries) is stored in the human brain as a kind of knowledge, which originates from continuous learning in people's daily lives (Chao and Martin, 1999). Studies have shown that this color knowledge can be described and generalized as a semantic conceptual model (Lu et al., 2010). Zeki and Marini (1998) found that different pathways were adopted for processing objects dressed in natural and unnatural colors and proposed a cognitive model based on color knowledge. Based upon an implicit experimental paradigm, Lu et al. (2010) revealed that color was a part of perceptual memory, which was activated automatically during information processing. They also found notable P2 activities in the early stages of processing objects with different colors. The amplitudes of P2 are larger for objects with appropriate color than for objects with inappropriate color and with gray color (Lu et al., 2010). In this study, larger P2 was elicited by warning signs with yellow backgrounds than those with blue and white backgrounds. It might be due to that after the earlier stages of perceptual processing (P1 and N1), the semantic concepts about different colors are retrieved and warning signs with yellow background is thought to be more natural than those with blue and white backgrounds. This finding was also evidenced by the self-report data, which showed that 79.0% of the respondents who took part in the questionnaire-based experiment could correctly indicate yellow as the background color for warning signs in the Chinese national standard.

Frontal N2 component has been found to play a role in stimulus classification (Cao et al., 2010; Lu et al., 2010; Nittono et al., 2010). For instance, Cao et al. (2010) examined the neural responses toward blue and yellow objects and found a notable N2 differentiation between these two colors. Moreover, in a study comparing how people respond to objects in different colors, it is noted that objects in their appropriate color induced a smaller N2 component than objects in their inappropriate color and objects in gray color (Lu et al., 2010). In the current study, N2 amplitudes were more positive for warning signs with yellow and blue backgrounds than those with white background. Yet there was no significant difference between warning signs between blue and yellow backgrounds. We surmise that warning signs with colored background might be perceived differently from warning signs with white background at this processing stage. Though the self-report data indicated warning signs with

yellow and white background was perceived as more hazardous than those with blue background, warning signs with white background might be deemed to be less appropriate for hazard communication (Braun et al., 1995).

P3 component generally indicates the allocation of attention resources related to post-perceptual stimulus evaluation and categorical processing (Polich, 2007; Holmes et al., 2008; Fu et al., 2017). Frontal P3 (or so-called P3a) has also been linked to the top–down switching of attention by frontal brain systems toward rare or physically alerting stimuli (Mccarthy et al., 1997). In a study comparing yellow and blue colors, it was found that yellow objects induced significantly larger P3 amplitude than blue objects (Cao et al., 2010). In addition, between-category stimuli could result in enhanced P3 activity compared to within-category stimuli (Holmes et al., 2008). The present study showed that an increased P3 was induced by warning signs with yellow background relative to those with white backgrounds. But no difference was found between signs with blue and white backgrounds. In consonance with extant literature, we speculate that the differentiation in P3 amplitude might be caused by categorical processing of the colors and warning signs with yellow background are thought to be more feasible for hazard communication than those with blue and white backgrounds. This interpretation was also supported by the self-report data, since a majority of respondents suggested that yellow was the most feasible background color for warning signs.

Theoretical Significance and Practical Implication

Theoretically, this research contributes to the literature on safety sign colors from the perspective of neural processing. Prior research has mainly adopted self-reports, which is susceptible to subjective bias. This study incorporates neuroscience technology and employs an implicit paradigm, which is conducive to understanding how people process sign color without explicit attention. Moreover, by focusing on background color, this research extends the literature on sign colors. This research also has practical implications. First, warning signs with yellow background is recommended to be used instead of warning signs with white or blue backgrounds, since the former is more prone to capture people's attention and alert people of potential hazards. Second, warning signs should be put in place where they are necessary to increase the likelihood of being processed by the audience because the present study suggests that people are able to perceive the hazards communicated by warning signs even if they do not explicitly pay attention to the signs.

Limitations and Future Research Directions

This study is subject to several limitations, some of which may open up opportunities for future research. First, only warning signs were considered in this study to eliminate possible confounding factors resulted from including different types of safety signs. According to the message communicated by safety signs and their functions, they could be broadly classified into prohibition, mandatory, warning, and guide categories (GB2894, 2008). The Chinese national standard recommends different colors for different types of safety signs. Therefore, future studies may explore how people process sign color by using different types of safety signs. Second, this research mainly examined three background colors (i.e., white, blue, and yellow). Further research could extend this line of research and figure out people's perception of warning signs with other background colors. Third, to offer a deeper insight into how people perceive sign colors, the colors should be tested by three primary colors of red, green, and blue as well as their combinations, and by taking the changes in brightness, hue, and saturation into consideration. The Chinese national standard fails to consider these factors, which suggests a promising avenue for future research. Fourth, the color of signal words, pictorials, and surrounding shapes are worthy of further research. Finally, the subjects of the EEG experiment were mostly undergraduate students. Their differences in safety education were not considered in the study. Further studies are warranted to recruit subjects with more diverse backgrounds to generalize the findings of the present study and to examine if safety education influences the way people perceive sign colors.

CONCLUSION

Overall, this study investigates the neural correlates of how people perceive warning signs with different background colors (i.e., white, blue, and yellow) with an implicit paradigm. The results show that both perceptual components (P1, N1, and P2) and post-perceptual components (N2 and P3) are induced by signs with different background colors. These results possibly suggest that people are able to identify the differences in sign colors and the hazard information conveyed by different colors, even though their attention are not readily directed toward the signs. It may also enlighten future research on related topics.

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 Internal Review Board of the Neuromanagement Lab in Zhejiang University. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

JY and JB conceived and designed the study. JY, HF, and JB performed the experiment and analyzed the data. JY, ZS, HF, and JB interpreted the data and drafted the manuscript. JY, ZS, YH, HF, XL, and JB reviewed and refined the manuscript. JB administered the project. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by Natural Science Foundation of Guangdong Province (no. 2017A030310466), National Project (no. AWS14J011 and no. CICO201903), and Philosophy and Social Sciences Foundation of Guangzhou (no. 2018GZQN33). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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Conflict of Interest: JY and XL were employed by company Zhejiang Zheshang Engineering Service of Equipment Co., LTD. JY was employed by company Zhejiang Provincial Economic Construction Investment Co., LTD. ZS and JB were employed by company Zhejiang Expressway Information Engineering and Technology Co., LTD. YH was employed by company Zhejiang State-owned Capital Operation Co., LTD.

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

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ORIGINAL RESEARCH
published: 15 June 2021
doi: 10.3389/fpsyg.2021.654360

Gender Differences in Transnational Brand Purchase Decision Toward Mixed Culture and Original Culture Advertisements: An fNIRS Study

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Culture strategy is very important for transnational brand marketing. Functional near-infrared spectroscopy (fNIRS) is a promising brain imaging modality for neuromarketing research. In the present study, we used fNIRS to explore the neural correlates of consumers' purchase decision on different cross-culture marketing strategies. Forty Chinese participants watched transnational brands and products advertised with photographs of the brands' original culture (the original culture advertisements) and advertised with photographs of Chinese culture (the mixed culture advertisements), respectively. The behavioral results showed that the female participants showed significantly higher purchase rate when watching the original culture advertisements than the mixed culture advertisements, whereas the male participants did not show significant preference between these two types. The fNIRS results further revealed that for the female participants, watching mixed culture advertisements evoked significant positive activation in the left dorsolateral prefrontal cortex and negative activation in the medial prefrontal cortex, which was not found in the male participants. These findings suggest possible cognitive and emotional differences between men and women in purchase decision making toward different cross-culture marketing strategy. The present study also demonstrates the great potential of fNIRS in neuromarketing research.

Keywords: functional near-infrared spectroscopy, culture mixing, neuromarketing, purchase decision, advertisement

OPEN ACCESS

Edited by:
Tao Liu,
Zhejiang University, China

Reviewed by:
Yafeng Pan,
Karolinska Institutet (KI), Sweden
Taolin Chen,
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *16 January 2021*
Accepted: *10 May 2021*
Published: *15 June 2021*

Citation:
Duan L, Ai H, Yang L, Xu L and Xu P (2021) Gender Differences in Transnational Brand Purchase Decision Toward Mixed Culture and Original Culture Advertisements: An fNIRS Study. Front. Psychol. 12:654360. doi: 10.3389/fpsyg.2021.654360

INTRODUCTION

Globalization has greatly promoted the international production and sales, providing new choices for global consumers and rich opportunities for transnational enterprises. Culture plays an important role in influencing the consumers' attitude and purchase intention toward a brand (Zhou et al., 2015; Choi et al., 2020). However, for a transnational brand, the cultures between its origin country and host country are usually very different. Culture difference may bring fashion and exoticism feelings to the host consumers and promote the sale (Batra et al., 2000; Strizhakova et al., 2008). On the other hand, it may also bring barrier to convey value and concept from the

marketers to the consumers. How to make the brands accepted by people in the host country of entirely different culture always challenge the transnational marketers (Theodosiou and Leonidou, 2003; Engelen and Brettel, 2011).

A popular marketing strategy to close this gap is to integrate the brand into the host country's local culture. For example, marketers can launch advertisements that embed their products into the host country's local famous scenic spots, legendary tales, or daily life. This strategy is expected to win the market by showing respect, friendship and sincerity to the host consumers (Wang and Lin, 2009; Wu, 2011). However, this strategy is not risk-free. Many transnational brands carry strong cultural information of their origin country, and they can even be viewed as symbols of their own culture (e.g., Apple is a cultural symbol of the Silicon Valley and American technology industry; Chanel represents the luxury culture of France). Integrating transnational brands into host culture usually generate culture mixing. Culture mixing refers to simultaneously presenting the representative symbols of different cultures in a same space (Chiu et al., 2009, 2011; Hao et al., 2016). Inappropriate culture mixing may induce people's exclusive reaction (Chiu and Cheng, 2007) by enlarging the perception of distance between the original culture and the host culture (Chiu et al., 2009; Torelli et al., 2011), evoking negative emotional experience (Tong et al., 2011b; Wu et al., 2014; Morris et al., 2015), and/or bringing perceived cultural threat (Cheng, 2012). It is a hot field to study cross-culture marketing strategy for transnational brands (Cui et al., 2012, 2016; Torelli and Ahluwalia, 2012; Peng and Xie, 2016; Shi et al., 2016).

Neuromarketing is a fast-developing field. With the help of the brain imaging techniques, researchers can non-invasively measure the consumers' neural activity. This technology offers marketing researchers opportunity to investigate the neural mechanism of the purchase behavior and discover subtle neural markers related to consumers' decision-making process (Ariely and Berns, 2010). Functional near-infrared spectroscopy (fNIRS) is a novel non-invasive brain imaging technology. It measures the brain's neural activity by monitoring the regional cerebral hemoglobin concentration changes (Boas et al., 2004). Compared with other modalities such as functional magnetic resonance imaging and electroencephalogram, fNIRS has many unique advantages such as low-cost, portable, comfortable, and insensitive to head motion (Hoshi, 2003). Moreover, fNIRS has relatively high temporal resolution and spatial resolution (Cutini et al., 2012). These advantages make fNIRS a very promising brain imaging modality. In recent years, pioneering studies have introduced fNIRS to culture and neural marketing studies (e.g., Murata et al., 2015; Kim et al., 2016; Çakir Murat et al., 2018; Krampe et al., 2018; Meyerding and Mehlhose, 2020). However, to our knowledge, few studies have utilized this approach to study cross-culture marketing strategy for transnational brands. Therefore, the present study motivated to explore the feasibility of using fNIRS to study the neural correlates of consumers' purchase decision toward different cross-culture marketing strategies for transnational brands.

In the present study, forty Chinese participants watched two different types of advertisements of a series of transnational brands and products. One type of advertisements emphasized a brand's original culture by presenting the brand with its original culture symbols (i.e., the original culture condition, OC). The other type of advertisements tried to integrate a brand into the host culture by presenting it with Chinese culture symbols (i.e., the mixed culture condition, MC). We measured the participants' neural activity by using fNIRS when they were watching the advertisements, and compared the participants' behavioral and neural responses between the two conditions. Moreover, previous studies suggested that cognitive and emotional differences widely exist between genders (Speck et al., 2000; Birditt and Fingerman, 2003; Labouvie-Vief et al., 2003; Goldstein et al., 2005). Therefore, we also examined the gender differences in the purchase decision under different conditions.

MATERIALS AND METHODS

Participants

Forty healthy college students (21.2 ± 2.1 years of age, 20 males, and 20 females) from Shenzhen University participated in this study. All the participants were right-handed, with normal or corrected-to-normal vision, and without any history of psychiatric or neurological disorders. The participants were recruited via the campus network bulletin board system. Every participant received ¥40 CNY (about $6 USD) for the participation. All the participants gave written informed consent in accordance with the Declaration of Helsinki before the experiment. The study protocol was approved by the Institutional Review Board at Shenzhen Key Laboratory of Affective and Social Cognitive Science, Shenzhen University.

Stimuli

Fifteen products of famous transnational brands were used in the present study (e.g., Adidas shoes, Apple mobile phones, and Chanel fragrance). Every product had two print advertisements (30 advertisements in total). Each advertisement consisted of a picture of the product, a logo of the brand and a background photograph. For one type of the advertisements (the mixed culture condition, MC), the background photograph contained significant Chinese culture symbols (e.g., the Great Wall or the Forbidden City), whereas for the other type of advertisements (the original culture condition, OC), the background photograph contained significant foreign cultural symbols (e.g., the Louvre of France or the Mount Rushmore of America). The advertisements were evaluated by another group of forty college student volunteers (20.9 ± 2.3 years of age, 20 males, and 20 females). For every advertisement, they rated how much the background photograph suited to advertise the brand and the product. For the mixed culture advertisements, they further rated how much they presented an integration of the brand and the product with Chinese culture, and for the original culture advertisements, they rated how much the advertisement presented an integration of the brand and the product with their original culture. The volunteers rated every

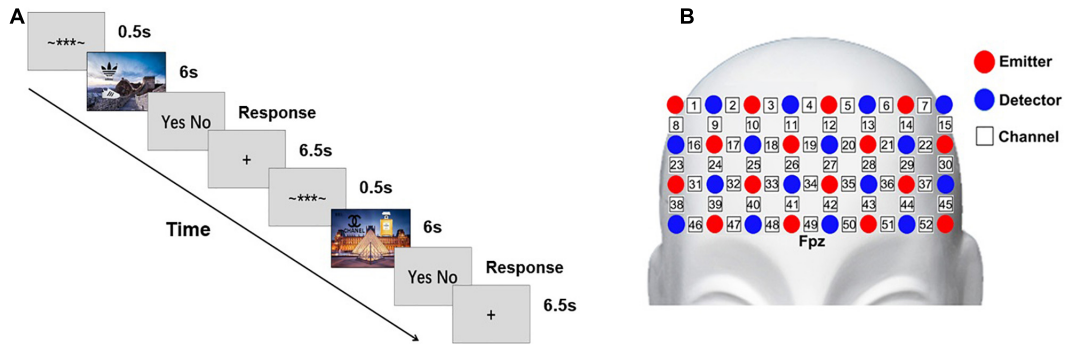

FIGURE 1 | Scheme of the experiment. **(A)** The paradigm of the experiment. **(B)** The configuration of the fNIRS probes.

question with a six-point scale (1 = not at all, 6 = very much; see **Supplementary Material**).

Procedure

During the experiment, the participants were instructed to watch the advertisements and make decision that whether to buy the product shown in each advertisement. The whole procedure consisted of 30 trials. Each trial began with an indicator on the screen for 0.5 s, and then an advertisement was presented for 6 s. After the advertisement, the participants were asked to answer whether they wanted to buy the product as soon as possible by pressing a keyboard. A central fixation cross was presented for 6.5 s after the participants responded and the participants were instructed to relax and rest before the next trial. The whole procedure takes about 7 min (**Figure 1A**). The advertisements were presented in pseudo random sequence and counterbalanced between the two conditions.

fNIRS Data Acquisition and Pre-processing

The fNIRS measurement was conducted with a NIRScout continuous wave fNIRS system (NIRx Medical Technologies, New York, NY, United States). A probe set containing 16 emitters and 16 detectors was placed on the frontal area, forming 52 measurement channels in total. The probe set was placed by approximately putting its bottom middle channel on Fpz of the international 10–20 system (Jasper, 1958; **Figure 1B**). The source-detector distance was 30 mm. The cortex localization of the optodes and channels was obtained by using the NIRSite software (NIRx Medical Technologies). The absorptions of the near-infrared lights at two wavelengths (785 nm and 830 nm) were measured with a sampling rate of 3.91 Hz. The oxygenated (HbO) and the deoxygenated (HbR) signals were calculated by using the modified Beer–Lambert law (Cope and Delpy, 1988). The differential pathlength factor were 7.25 and 6.38 for 785 nm and 830 nm, respectively (Hiraoka et al., 1993). The wavelet-based method (Duan et al., 2018) was applied to remove the superficial physiological noise in the signal. Then the signal was 0.01–0.2 Hz bandpass filtered to remove the low-frequency drift and the high-frequency noise (Zhang et al., 2017).

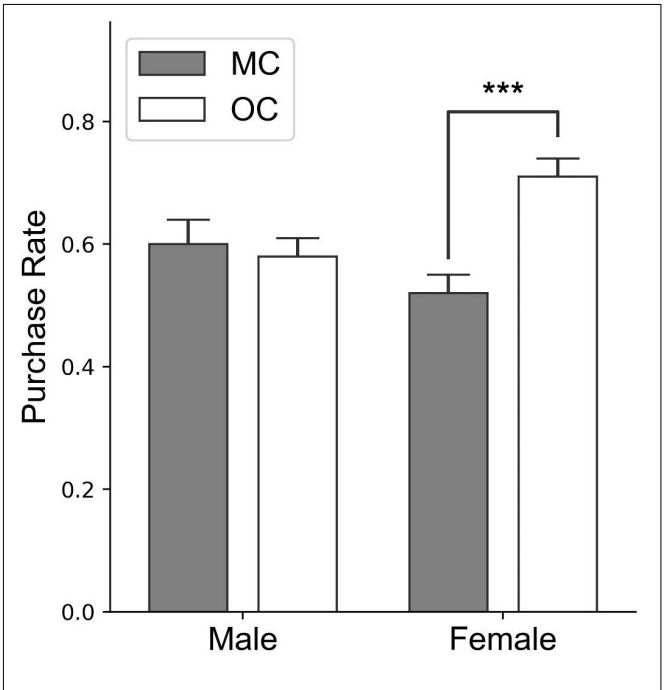

FIGURE 2 | Behavioral results. The *y*-axis represents the purchase rate. Error bars denote the standard error. MC: the mixed culture condition. OC: the original culture condition. ***: $p < 0.001$.

fNIRS Data Analysis

The neural responses were analyzed by the general linear model approach. The regressor corresponding to each condition was generated by convolving the stimuli series with the canonical hemodynamic response function. In the individual level, the model parameters were estimated channel-by-channel for all the participants. Then the mixed effect model-based group-level activation t-maps were calculated by conducting a one-sample *t*-test on all individual parameters (Holmes and Friston, 1998; Lu et al., 2010). The activation maps of the MC condition, the OC condition, and the contrast between the two conditions (MC – OC) were generated, respectively. Only the HbO signal was used to conduct the analysis because of its high signal-to-noise ratio

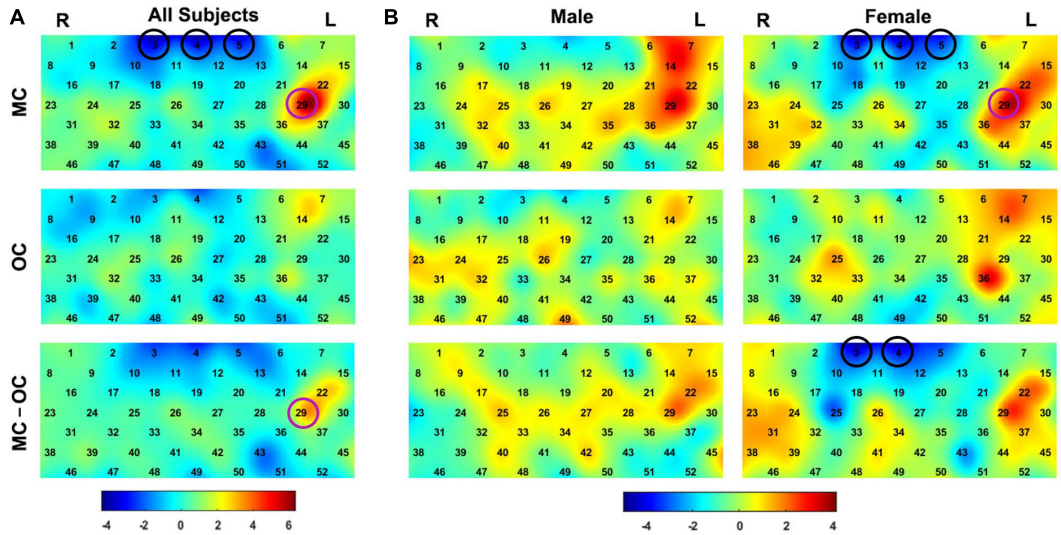

FIGURE 3 | The group-level activation *t*-maps for all the participants **(A)** and for different gender **(B)**. The black circles marked the significantly negatively activated channels in mPFC, and the purple circles marked the significantly positively activated channels in dlPFC. MC: the mixed culture condition. OC: the original culture condition.

(Tong et al., 2011a). All the analysis were conducted with custom programmed MATLAB script.

RESULTS

Behavioral Results

To validate the stimulus materials, the advertisements were rated by other volunteers than the participants engaged in the fNIRS study. For the question that how much the background photograph suited to advertise the brand and the product, all the advertisements got high average ratings, and no significant difference was observed between the MC and the OC conditions (4.93 ± 0.15 for MC and 4.90 ± 0.19 for OC, $p = 0.66$). Moreover, for the question that how much the advertisements presented an integration of the brand and the product with Chinese culture, the MC advertisements got an average rating of 4.86 ± 0.16, whereas for the question that how much the advertisements presented the original culture that the brand and the product belong to, the OC advertisements got an average rating of 4.86 ± 0.10, and no significant difference was observed between the MC and the OC advertisements ($p = 0.96$). These results suggested that both the MC and the OC advertisements had good quality in design and cultural representativeness.

The participants' purchase rates were analyzed by using two-way ANOVA. Neither of the main effects (advertisement type and gender) was found significant, whereas their interaction was significant [$F(1, 39) = 7.835$, $p = 0.007$, and $\eta_p^2 = 0.094$]. The simple effect analysis revealed that for the female participants, the original culture advertisements induced significantly higher purchase rate (0.71 ± 0.16) than the mixed culture advertisements (0.52 ± 0.15, $p = 6.98 \times 10^{-4}$), and for the male participants, the difference between purchase rates toward the original culture advertisements (0.58 ± 0.17) and the mixed culture advertisements (0.60 ± 0.20) was insignificant ($p = 0.72$; **Figure 2**).

fNIRS Results

As shown in **Figure 3A**, the MC condition showed significant positive activation in the left dorsolateral prefrontal cortex (dlPFC) [BA 46, channel 29 ($p = 3.62 \times 10^{-8}$)] and negative activation in the medial prefrontal cortex (mPFC) [BA 9, channel 3 ($p = 8.77 \times 10^{-6}$), channel 4 ($p = 1.31 \times 10^{-5}$), and channel 5 ($p = 2.10 \times 10^{-4}$)], whereas the OC condition did not show any significant activation channels. MC showed significantly higher response than OC in the dlPFC [BA 46, channel 29 ($p = 5.90 \times 10^{-4}$)].

We further conducted the same analysis on the male and the female participants, respectively. As shown in **Figure 3B**, for the MC condition, the female participants showed significant positive activation in the left dlPFC [BA 46, channel 29 ($p = 5.21 \times 10^{-4}$)] and negative activation in the mPFC [BA 9, channel 3 ($p = 1.48 \times 10^{-5}$), channel 4 ($p = 2.89 \times 10^{-5}$), and channel 5 ($p = 6.09 \times 10^{-4}$)], and the male participants showed no significant activation. For the OC condition, neither the male nor the female participants showed significant activation. Moreover, for the female participants, MC showed significantly lower response than OC in the mPFC [BA 9, channel 3 ($p = 2.00 \times 10^{-5}$), and channel 4 ($p = 4.49 \times 10^{-5}$)]. All significances reported above were at $p < 0.05$, Bonferroni corrected.

DISCUSSION AND CONCLUSION

Culture difference is an important issue in transnational marketing. In the present study, we simulated a virtual

purchase scenario and measured the behavioral and neural responses toward two types of advertisements of different cross-culture marketing strategy (i.e., the mixed culture advertisement and the original culture advertisement). Behaviorally, we found that the female participants showed significantly higher purchase rate when watching the original culture advertisements than the mixed culture advertisements, whereas the male participants did not show significant preference between these two types. The fNIRS results further revealed that for the female participants, watching mixed culture advertisements evoked significant positive activation in the left dlPFC and negative activation in the mPFC, which was not found in the male participants.

In our experiment, the integration of the transnational brands with the Chinese culture symbols presented prominent culture mixing characteristics. Previous studies suggested that emotion can mediate the response to the multicultural experience (Cheng et al., 2011; Wu et al., 2014). It was also suggested that culture mixing may evoke the participants' perception to external threats to the fidelity of in-group identity and therefore induce disgust emotion (Cheon et al., 2016). This negative emotion may further influence the cognitive information processing and the consequent decision making (Matthews and Levin, 2012). The female is generally regarded as "more emotional" than the male, and show stronger emotional physiological and neural responses than the male during emotion processing (Kring and Gordon, 1998; Labouvie-Vief et al., 2003; Hofer et al., 2006; Koch et al., 2007). Therefore, compared with the male participants, the female participants may be more sensitive to the negative influence induced by culture mixing. In the present study, we found that the female participants showed significantly lower purchase rate in the MC condition than in the OC condition, and the fNIRS results further revealed significant negative mPFC activation in the MC condition other than in the OC condition. A previous fNIRS study suggested that negative emotion stimuli could evoke negative activation in mPFC (Huang et al., 2017). Therefore, these findings indicated that the mixed culture advertisements used in the present study might induce more negative emotional experience to the female participants than the male participants, thus leading to lower purchase rate.

Cognitive fluency is another factor that may affect the response to culture mixing (Shapiro, 1999). It is suggested that individuals with high cognitive fluency precepted in processing a brand stimulus tend to make positive evaluations and *vice versa* (Lee and Labroo, 2004). It is also suggested that culture mixing may affect cognitive fluency and thus cause reduced evaluations to a brand (Torelli and Ahluwalia, 2012). In our experiment, the brand and the background photograph were culturally consistent in the OC condition. This congruency effect may facilitate the cognitive fluency. dlPFC plays critical roles in cognitive control, including receiving conflict detection signal, adjusting and reallocating cognitive resources, attention control and conflict resolving (Blais and Bunge, 2009; Bartoli et al., 2018). Interestingly, the present study found significant positive activation in the left dlPFC in the MC condition for the female participants, which may suggest that the female participants have lowered cognitive fluency when processing the mixed culture advertisements with prominent cross-culture property.

Neuromarketing approaches allow researchers to better understand various of complex purchase decision phenomena and make more comprehensive assessment of a marketing strategy, by analyzing the underlying neurobiology which are neglected or unavailable in traditional behavioral studies. The present study provided a preliminary example of using fNIRS in studying the transnational brands' cultural marketing strategy. Our results suggested that fNIRS could effectively capture the neural responses to the cognitive and emotional processing in purchase decision making. Beyond our current experiment, fNIRS has great potential to provide experimental environment much closer to the daily life and support larger sample size of participants to assist practical transnational marketing strategy research.

This study also has several limitations that will be improved in our future works. First, the present study did not measure the participants' emotion which may play an important role in cross-culture processing (Wu et al., 2014; Cheon et al., 2016). Second, the present study did not regard the properties of the brands and products (e.g., male-oriented or female-oriented) that may bring bias to the decisions of different gender. Third, it is necessary to use larger sample size for each gender to further confirm the current discovery.

In conclusion, the present study revealed the neural correlates of processing the original culture advertisements and the mixed culture advertisements for transnational brands. It validated the feasibility of applying fNIRS to study cross-culture marketing strategies for transnational brands and demonstrated its potential in neuromarketing research. The present study may also shed light on understanding the neural mechanism of culture mixing.

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 Institutional Review Board at Shenzhen Key Laboratory of Affective and Social Cognitive Science, Shenzhen University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LD and PX designed the research. LY and LX performed the experiments. LD and HA analyzed the data. LD drafted the work. All authors contributed to the article and approved the submitted version.

FUNDING

This study was supported by the National Natural Science Foundation of China (31871137, 61503030, 31920103009, 31700959, and 72081360454), Young Elite Scientists Sponsorship Program by China Association for Science and Technology (YESS20180158), the Major Project of National Social Science Foundation (20&ZD153), Guangdong International Scientific Collaboration Project (2019A050510048), Guangdong Key Basic Research Grant (2018B030332001), Shenzhen-Hong Kong Institute of Brain Science-Shenzhen Fundamental Research Institutions (2019SHIBS0003), Natural Science Foundation of Guangdong Province, China (2020A1515011394), Shenzhen Science and Technology Research Funding Program (JCYJ20180305124819889, JCYJ20180507183500566, and JCYJ20190808121415365), and Shenzhen Peacock Program (827-000235).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.654360/full#supplementary-material

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

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frontiers in Psychology

SYSTEMATIC REVIEW
published: 01 July 2021
doi: 10.3389/fpsyg.2021.687404

Past, Present, and Future of Impulse Buying Research Methods: A Systematic Literature Review

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Impulse buying (IB) represents a pivotal subject in consumer psychology. A general agreement on its core elements and their relationship is arguably established. So far, however, there has been little discussion about how to assess impulse purchases, leading to a potential divergence of practise from theory and complexities in cross-study comparability. This systematic literature review investigates the research methods and metrics employed in high-quality literature to evaluate impulse shopping behaviours across different environments, including online, offline, and multichannel settings. Following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) criteria, the literature search has been conducted on databases relevant for scientific literature, including Scopus, Web of Science, and ProQuest. Fifty-four articles were included in this systematic review. Findings show the existence of four methods to investigate IB, namely quantitative self-reports, laboratory investigations, fieldwork observations, and qualitative interviews. A comparison of the four methods in terms of fit highlights that self-reports and interviews provide a significant contribution in assessing the cognitive facet of impulse purchasing. Laboratory investigations and fieldwork observation find a better fit with the conative and visceral facets of impulsive buying. Considering the major role of affective charges occurring during impulse shopping, complementary research approaches, and metrics belonging to applied psychophysiology and consumer neuroscience are examined. Three opportunities for future research are discussed, including theory building and refinement, understanding individual differences, and honing behavioural predictions.

Keywords: impulse buying, impulse purchase, systematic review, consumer behaviour, consumer neuroscience, neuromarketing

OPEN ACCESS

Edited by:
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Reviewed by:
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University of Almeria, Spain
Marianela Denegri,
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *29 March 2021*
Accepted: *07 June 2021*
Published: *01 July 2021*

Citation:
Mandolfo M and Lamberti L (2021) Past, Present, and Future of Impulse Buying Research Methods: A Systematic Literature Review. Front. Psychol. 12:687404. doi: 10.3389/fpsyg.2021.687404

INTRODUCTION

Impulse buying (IB) represents an established topic in consumer psychology. Several reviews find common ground in describing it as a multifaceted construct, which includes conative, visceral, and cognitive factors (Xiao and Nicholson, 2013; Amos et al., 2014; Chan et al., 2017; Iyer et al., 2020). From its conative side, IB is conceptualised as an act with no pre-shopping intentions driven by immediate self-fulfilment (Rook, 1987; Rook and Fisher, 1995; Beatty and Ferrell, 1998). Conative expressions of IB also include rapid decision-making and on-the-spot actions (Piron, 1991; Lades, 2014). Concerning its visceral facet, IB involves a compelling psychological urge to purchase and a powerful emotional charge (Rook and Gardner, 1993; Wood, 1998; Baumeister, 2002). Impulse

buying further stimulates emotional conflict in the post-purchase due to its hedonic content (Puri, 1996; Dittmar and Drury, 2000). Third, regarding its cognitive aspect, IB favours short-term gains triggered by the urgency to seek immediate gratification. This drive appears to be triggered by alluring desires towards the possession of a product (Rook and Hoch, 1985; Dholakia, 2000) and has been related to fallacious intertemporal decisions, where immediate smaller rewards are favoured on delayed greater rewards.

Impulse buying has been investigated from different perspectives (Verplanken and Sato, 2011) and a general agreement on its core elements is arguably established in the literature (Xiao and Nicholson, 2013). So far, however, there has been little discussion about how to assess impulse purchases. This scant consideration of assessment methods might lead to inconsistencies in research. First, inconsistencies between the theoretical conceptualisation of IB and its actual measurement may lead to a divergence of practise from theory. This misalignment mines theory confirmations or confutations and it tends to increase the distance between academics and practitioners (Kumar, 2017). Second, the absence of empirical standards for IB assessment may hamper cross-study comparability in upcoming research. A lack of a common method may further hinder replicability and lead to fragmentation within the same field of research, which is a documented concern in actual IB research (Xiao and Nicholson, 2013; Chan et al., 2017).

The present work intends to bridge this gap by systematically investigating the methods and metrics employed in consumer research to assess IB across different environments, including online, offline, and multichannel settings. This paper offers the scholarly community a consolidated overview of approaches employed in consumer behaviour research. We discuss past and current methods as well as emerging techniques highlighting their features in the different contexts of use. Our argumentations follow a positivist perspective, positing that the facets of IB might be assessed through measurements. This stance seemingly appears to be shared by the greater majority of authors delving into the topic (Beatty and Ferrell, 1998; Hausman, 2000). Along these lines, our intended contribution is two-fold. First, we advance suggestions concerning the suitability of each research method to different research goals. Through a direct comparison of the research methods employed in IB research, we provide indications about the type of research approach and metrics that might be appropriate depending on the context and the specific facet of IB. Second, we provide suggestions about possible metrics borrowed from parallel fields to complement existing research approaches and set directions for forthcoming work.

The remainder of this paper is structured as follows. First, we describe our review methodology, including literature search, selection, and coding. Next, we present our analysis of the literature. Based on the findings of our review, we discuss the fit with IB research of each approach and consider the existing methodological gaps. Lastly, we advance potential directions for future work.

REVIEW METHODOLOGY

A systematic literature review was conducted to analyse IB assessment methods. This approach was chosen due to the maturity of the topic in the marketing and consumer behaviour literature and to foster replicability of results. The 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used for this article (Page et al., 2021).

Eligibility Criteria

The initial phase of the research process required defining the search wordings and research boundaries. To avoid an overly narrow stance, our definition of IB included reminder, planned, suggestion, and pure impulse purchases as described by Stern (1962). Likewise, we adopted an extensive selection of research methods including both qualitative approaches (e.g., focus groups, ethnographic studies) and quantitative approaches (e.g., quantitative self-reports, laboratory investigations). Based on these assumptions, we employed a three-layer query. The first layer of the query scanned for documents containing the term "Impulse buying" and the related declinations (i.e., "impulsive buy," "impulse buy") in their title, abstract or keywords. Further synonyms were introduced in line with previous reviews (Xiao and Nicholson, 2013; Chan et al., 2017), including "impulse purchase," "impulse shopping," and "impulse consumption." The second layer searched for keywords linked to measurement and assessment methods (e.g., "determinant," "measure") and the related synonyms or plurals. The third layer was intended to exclude studies with psychiatric implications (i.e., investigating the sphere of compulsive behaviours), according to the area of investigation of the present study. Therefore, we excluded forms of "compulsive" buying. Since IB behaviours are generally independent of sociodemographic variables (Amos et al., 2014), no further filter was set concerning the population's characteristics.

Search Strategy and Selection Process

As the existing IB literature is highly interdisciplinary, we queried different databases, namely ScienceDirect/Scopus, Web of Science, and ProQuest. Additional studies were also located by searching papers referenced in listed articles. All the additional articles were retrieved through snowballing from the sample articles. These included studies cited in the methodology as the seminal studies (e.g., Kacen and Lee, 2002; Mattila and Wirtz, 2008) or research method (e.g., Weinberg and Gottwald, 1982).

The structured query included filter related to subject areas, language, and document type. We selected subject areas linked to business and management fields, psychology, as well as social sciences. The documents included were limited to peer-reviewed research published in English, thus excluding conference proceedings and book chapters. An example of the specific query employed on Scopus is reported in **Supplementary Figure 1** among **Supplementary Material**.

The search phase resulted in the collection of 258 documents. All the gathered documents were successive to the seminal paper introducing the concept of IB in the marketing literature, namely Stern (1962), therefore congruent with the chosen definition of

IB. In particular, the selected literature ranged from 1982 to 2020. In the screening phase, duplicates were removed based on abstract screening. A total of 93 articles was removed at this stage.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were applied to ensure sample reliability. Inclusion criteria were employed to include high-quality literature. First, to ensure the selection of high-quality research and the appropriate coverage of a wide selection of academic journals, we narrowed our sample by focusing on high-ranked journals. In line with Morris et al. (2009), we included only papers belonging to 2, 3, and 4-rated journals based on the Chartered Association of Business Schools' 2018 Academic Journal Guide (AJG 2018). Seventy nine research papers were excluded after this stage.

Based on the analysis of full texts, we excluded 25 cases where IB was not the main object of the study. Accordingly, we excluded research papers where IB was considered an antecedent of other constructs deemed beyond the present research scope (e.g., store patronage, bidding behaviours). Next, exclusion criteria aimed at removing studies having no empirical results (i.e., cases presenting only theoretical models of IB were excluded). A total of seven documents was excluded after this stage. To minimise the risk of bias, inclusion and exclusion criteria were independently evaluated by the two authors. Overall, 54 documents were deemed relevant at the end of the search process. **Figure 1** illustrates the flowchart of the study selection process, which was based on the PRISMA 2020 protocol (Page et al., 2021).

Information Extraction and Coding

The following step of the review process concerned the categorisation of the gathered literature. To systematically document the cataloguing process, we extracted the following information from each study: (i) research approaches, namely the typology of research to investigate IB (e.g., self-reports, focus groups, laboratory investigations); (ii) metrics to assess or measure IB (e.g., the proportion of items bought on impulse); (iii) data collection technique (e.g., questionnaires, devices for data gathering); (iv) data analysis technique [e.g., structural equation modelling (SEM), econometric models]; (v) sample size; and (vi) typology of IB (i.e., in-store, online, multichannel, generic).

RESULTS

Characteristics of the Studies

Despite being a well-established construct in the consumer behaviour literature, the assessment of IB appears to be mainly developed in the last two decades. Beatty and Ferrell (1998) might be deemed the seminal paper for pioneering the application of SEM to multiple hypothesis testing. The last decade saw the starkest development in terms of published research with 31% of the total publications in the period 2010–2015 and 39% from 2016 to 2020. The advent of the internet allowed to broaden the conceptualisation of IB, framing it also in the online environment (Adelaar et al., 2003; Parboteeah et al., 2009). Accordingly, our sample shows not only studies analysing IB in the general context (41%), but a relevant part concerns the online setting (33%). The remaining slice encompasses both studies investigating IB in specific in-store sites (22%) or multichannel realities (4%), where consumers had interactions with both digital tools and brick-and-mortar realities (e.g., Bellini and Aiolfi, 2019).

Approaches to Investigate Impulse Buying

The large majority of the collected studies (94%) adopted quantitative approaches in assessing IB. Among these, we observed a prevailing line relying on self-reports (63%), laboratory investigations (26%), and fieldwork observations (11%). Alternative qualitative methods prove to be entirely based on face-to-face interviews.

Quantitative Self-Reports

Self-reports were often assessed through closed-ended scales evaluating the level of agreement on agree-disagree scales or between semantic items. These scales were regularly adapted from multiple-item scales present in the prior marketing literature (Silvera et al., 2008; Lucas and Koff, 2014) or on established psychometric reference scales (Mehrabian and Russell, 1974; Watson et al., 1988). Alternative approaches to assess IB were found in hypothetical scenarios descriptions investigating the personal evaluations of the respondent on semantic close-ended scales (Chih et al., 2012; Liu et al., 2013).

Impulse Buying appears to be assessed through self-reports either as a personality trait or as a measure of recalled past acts of buying. Impulse buying-related personality traits prove to be entirely assessed through multiple-item scales, though not univocally defined. The case of IB tendency is emblematic. Three different major scales are employed to assess IB tendency, namely the ones developed by Rook and Fisher (1995), Weun et al. (1998), and Verplanken and Herabadi (2001). The 9-item scale developed by Rook and Fisher (1995) appear to be the most frequently used tool (tallied 16 times as significant), while the other two scales are frequently used as well (each tallied 7 times). No relevant difference was spotted in the temporal adoption of any of the three, being all used both in earlier (Beatty and Ferrell, 1998; Kacen and Lee, 2002; Silvera et al., 2008) and recent research (Bellini et al., 2017; Liu et al., 2019; Meng et al., 2019). Content-wise, the scale developed by Verplanken and Herabadi (2001) takes a different angle, discriminating between cognitive and affective facets of the phenomenon and hence proves to be more often adopted in psychology-related studies (Lucas and Koff, 2014, 2017). To the best of our knowledge, no specific study has tackled the issue of comparing the three scales in terms of effectiveness. Notwithstanding, more recent studies contributed to the development of further scales that consider also the conative facet of IB in a cross-cultural setting (Sharma et al., 2014) or assess it as a transient individual state reflecting temporary depletion of self-regulatory resources (Lucas and Koff, 2014). It is relevant to note that other significant personality traits are mostly assessed through established scales adopted in other research fields, including marketing, sociology, and psychology (Das, 2016; Olsen et al., 2016; Meng et al., 2019). This underscores the interdisciplinary interest in assessing IB behaviours.

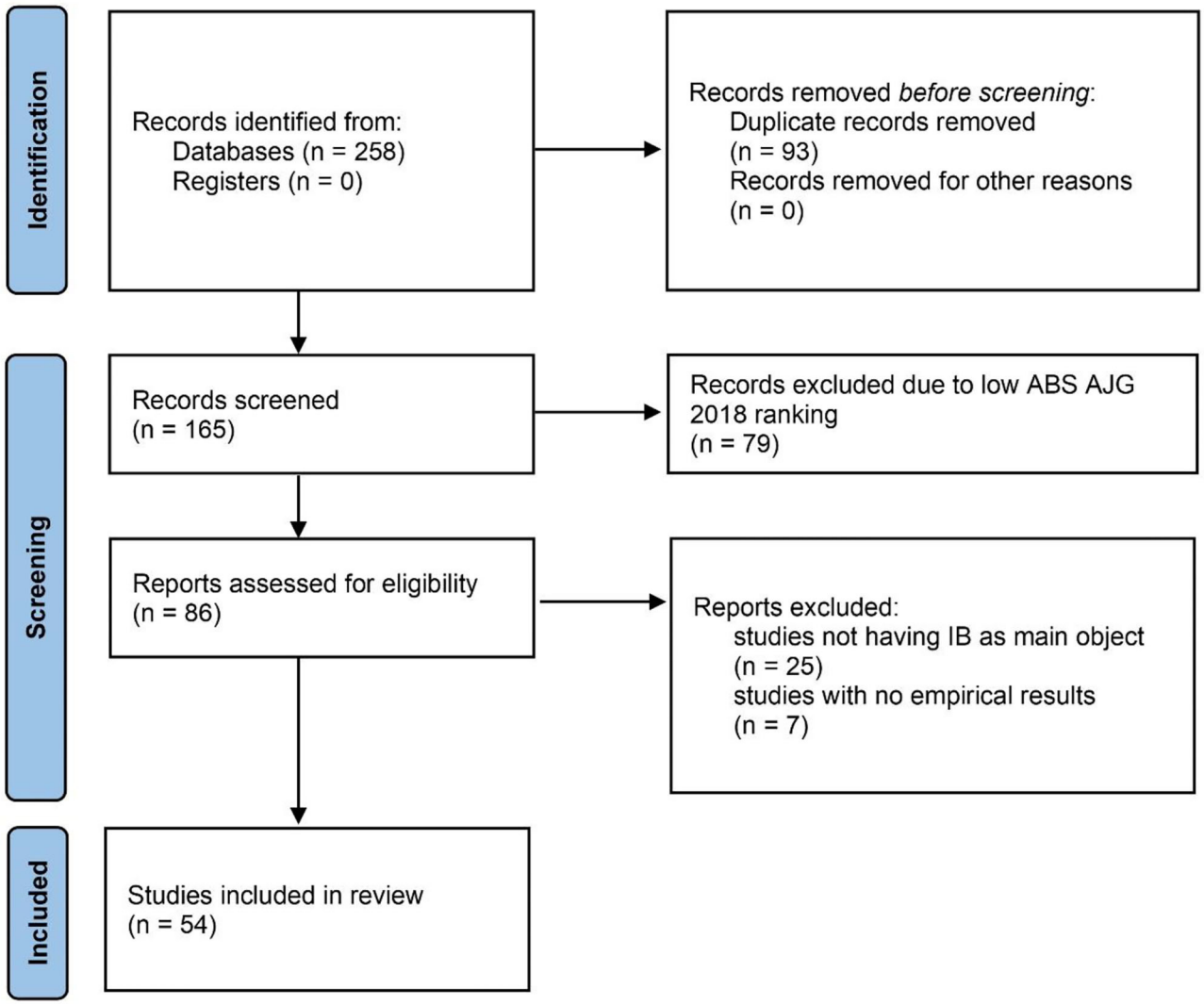

FIGURE 1 | Flow diagram depicting identification and screening process.

The investigation of recalled acts of buying is variegated. Direct queries are frequently used to determine the essence of the purchase. These are recorded through multiple-item Likert scales evaluating the unplanned side of IB (e.g., "I ended up spending more money than I originally set out to spend," and "I bought more than I had planned to buy," Mattila and Wirtz, 2008, p. 564), its spontaneity (Verhagen and Van Dolen, 2011), or single direct question (i.e., "How often do you buy things on impulse?," Kacen and Lee, 2002, p. 167). Alternatively, the perceived urge to buy was employed as a proxy of IB behaviours, assessed on multiple-item Likert scales (e.g., "I had the urge to purchase items other than or in addition to my specific shopping goal," Parboteeah et al., 2009, p. 67). A further method based on self-reports consisted in the employment of imaginary shopping situations. These require the subjects to deviate from any personal shopping goal and project themselves into a hypothetical shopping scenario suggesting a purchasing choice to a fictional third character (e.g., "Mary is a 21-year-old college student with a part-time job," Rook and Fisher, 1995, p. 308). **Table 1** summarises IB metrics, their description with the related primal reference scale, and reference studies.

Results showed that closed-ended surveys represent the most adopted data collection instrument. Nevertheless, discrepant strategies for data collection were observed. A consistent part of the studies employed either directly handed-out surveys or online surveys (Sun and Wu, 2011; Liu et al., 2013). Other study protocols favoured mall-intercept methods involving customers in stores before and after their shopping experience (Beatty and Ferrell, 1998; Mohan et al., 2013; Bellini et al., 2017). Further pieces of evidence point out the use of consumer shopping diaries combined with questionnaires to restrain from the presence of the interviewer (Jones et al., 2003). Among the studies employing self-reports, the respondent sample proved variable in size, averaging roughly 400 respondents.

TABLE 1 | IB metrics assessed through quantitative self-reports.

	IB metric	Description	Primal reference scale	Reference study
IB-related personality traits	Impulse buying tendency	Individual disposition to buy on impulse	Rook and Fisher, 1995	Kacen and Lee, 2002; Jones et al., 2003; Vohs and Faber, 2007; Parboteeah et al., 2009; George and Yaoyuneyong, 2010; Sun and Wu, 2011; Hubert et al., 2013; Liu et al., 2013; Serfas et al., 2014; Chen and Wang, 2016; Das, 2016; Olsen et al., 2016; Chung et al., 2017; Khachatryan et al., 2018; De Vries and Fennis, 2019; Meng et al., 2019
			Weun et al., 1998	Beatty and Ferrell, 1998; Kacen and Lee, 2002; Adelaar et al., 2003; Chih et al., 2012; Mohan et al., 2013; Shukla and Banerjee, 2014; Bellini et al., 2017
			Verplanken and Herabadi, 2001	Silvera et al., 2008; Lucas and Koff, 2014, 2017; Dhaundiyal and Coughlan, 2016; Olsen et al., 2016; Bossuyt et al., 2017; Liu et al., 2019
	Overall consumer impulsiveness	Cross-cultural disposition to purchase impulsively	Sharma et al., 2014	Sharma et al., 2014
			Mittal et al., 2016	Mittal et al., 2016
	Impulsive behaviour	Individual disposition to act on urges with little deliberation or evaluation of consequence	Puri, 1996	Sharma et al., 2010; Hubert et al., 2013, 2018
			Whiteside and Lynam, 2001; Cyders et al., 2007	Lucas and Koff, 2014
Act of buying	Impulse buying behaviour	Expression of impulsive buying behaviour during the act of purchase	Mattila and Wirtz, 2008	Mattila and Wirtz, 2008; Badgaiyan et al., 2017; Meng et al., 2019
			Verhagen and Van Dolen, 2011	Verhagen and Van Dolen, 2011; Chung et al., 2017
			Kacen and Lee, 2002	Kacen and Lee, 2002; Lee and Kacen, 2008
			Yoon, 2013	Yoon, 2013
			Badgaiyan et al., 2017	Badgaiyan et al., 2017
	Recent impulse buying behaviour	Individual transient impulse buying behaviour	Lucas and Koff, 2014	Lucas and Koff, 2014
	Impulsive purchase decision	Willingness of a customer to perform the act of purchase	Rook and Fisher, 1995	Parboteeah et al., 2009; Chih et al., 2012; Chen and Wang, 2016
	Felt urge to buy impulsively	State of desire experienced upon encountering a purchasing object	Luo, 2005	Luo, 2005; Chen and Wang, 2016; Meng et al., 2019
			Parboteeah et al., 2009	Parboteeah et al., 2009; Liu et al., 2013; Chen et al., 2019
			Adelaar et al., 2003	Adelaar et al., 2003; Martínez-López et al., 2020

The greater part (71%) involved between 200 and 600 respondents, while larger (11%) and smaller (18%) samples were observed as well. Given the multi-faceted nature of IB, larger samples were common practise to meet the minimum sample size to perform SEM in the subsequent data analysis. Data analyses based on self-reports were frequently carried out through SEM (46% of total quantitative studies), whereas econometric models or inferential analyses accounted for the remaining part.

Laboratory Investigations

Our findings point out a variegated pool of laboratory investigations. These are intended to induce and observe IB in an artificial and controlled environment. Notable laboratory

investigations are found both in online IB explorations (Adelaar et al., 2003; Parboteeah et al., 2009) and in general offline IB behaviours (Weinberg and Gottwald, 1982; Vohs and Faber, 2007). Such experimental tests follow experimental designs focused on either eliciting actual IB behaviours against controlled responses or manipulating contextual variables to assess their impact on purchasing intentions. For instance, Weinberg and Gottwald (1982) recreated a situation where subjects decided spontaneously on purchasing real products. Likewise, Bossuyt et al. (2017) conceived a real shopping task where participants, after receiving a budget from a predetermined lottery, faced either a category of products with high or low hedonic components (i.e., sweet snacks or rice and pasta). Differently, Adelaar et al. (2003) tested three distinct digital media characterised by different cues to assess their impact on urges to buy impulsively.

Different experimental investigations analyse the behavioural expression of IB. A prominent experimental design was employed by Vohs and Faber (2007) to explore the effect of self-regulatory resources depletion. Through three experiments, the authors initially depleted individuals' cognitive resources through attention-control tasks. Afterwards, participants received a monetary endowment and faced the decision to either pocket the money or use a part to perform an immediate purchase. Willingness to pay, the amount spent, and the purchased quantity were employed as dependent variables. A second notable example is provided by De Vries and Fennis (2019) who examine through a multiple-study how local brands may induce low-level construals, promoting IB behaviours. Through an online study, subjects faced an actual website selling actual products characterised by different brand positioning, which could be voluntarily purchased exchanging the monetary endowment related to their participation.

A few studies adopted a radically distinct approach, proposing to assess IB, and the related visceral activations from the physiological and behavioural responses of the participant. Early studies conceptualised the possibility to assess the perceived arousal during IB processes through electrodermal activations (Weinberg and Gottwald, 1982), whereas recent studies tested its methodological applicability (Bossuyt et al., 2017). Other research studies employed functional Magnetic Resonance Imaging to measure sub-cortical neural activations in conjunction with stimulating product packaging to delve into the underlying visceral processes characterising an impulse purchase (Hubert et al., 2013, 2018). Further studies assessed the affective state related to the act of impulse purchase from the ocular patterns and pupil dilation of the user, as a proxy of physiological arousal (Huang and Kuo, 2012; Serfas et al., 2014; Khachatryan et al., 2018). Further evidence of the manifestation of arousal through facial mimic was provided by Weinberg and Gottwald (1982) who monitored the facial expressions of buyers and non-buyers during a potential act of purchasing. **Table 2** shows the observed IB metrics assessed in the laboratory setting with the related indicators and reference studies.

These laboratory investigations remarkably share some common features. First, participants usually lack prior awareness of the purchasing possibility. The creation of a setting devoid of anticipatory cues pointing to a purchasing context recalls the unplanned nature of an impulsive purchase characterised by no pre-shopping intentions (Stern, 1962; Rook, 1987). Second, these experimental designs grant the possibility of performing a deliberate purchase. The spontaneous purchasing decision echoes the characteristic of IB behaviours of being on-the-spot decisions (Piron, 1991). Third, the conceived designs provide a monetary endowment framed as compensation for the participation. Giving a monetary sum that can be instantly disbursed instead of pocketed results to trigger the conative facet of IB, triggering urgency to seek immediate gratification (Rook and Hoch, 1985; Hoch and Loewenstein, 1991).

Fieldwork Observations

The third approach involves the assessment of IB in the actual shopping context. Research studies following this approach investigate the outcome of actual purchases in a naturalistic setting, commonly a shopping venue. For instance, Beatty and Ferrell (1998) adopted mall-intercept surveys pre- and post-shopping experience, comparing the actual purchases with initially planned ones. The method implies a first contact, where the subjects are asked to identify their shopping plans, which are then compared with the actual purchases after the shopping trip to discriminate the nature of the buying process. Similar methods investigated the proportion of unplanned purchased items (Mohan et al., 2013; Bellini et al., 2017) or the number of actual impulse purchases gathered from individual shopping diaries (Jones et al., 2003). A further notable setting is found in the application of Virtual Reality. Schnack et al. (2019) recreated an immersive virtual convenience store where subjects had to perform actual purchases while behavioural metrics were tracked. In **Table 3** we report the spotted IB metrics assessed through fieldwork observations with the related reference studies.

Fieldwork observation follows a naturalistic stance of investigation, embracing principles of ethnographic studies, namely non-participant observation of the purchasing process. Accordingly, the assessment of IB behaviours is reflected in actual purchases, commonly without any manipulation of environmental variables. It is worthwhile to note that all the empirical observations were paired with post-experience surveys. These are often aimed at assessing further variables such as personality traits or perceived affective states (e.g., Beatty and Ferrell, 1998; Mohan et al., 2013).

Qualitative Interviews

The fourth approach is represented by interviews. Our results show that interviews delving into IB follow a semi-structured format resembling an open and naturalistic conversation with a single respondent (e.g., Dittmar et al., 1995). The technique involves a thematic text analysis, namely an interpretation and a further categorisation of verbal information into theme-based patterns related to the understanding of meanings and motivations associated with IB episodes (Dittmar and Drury, 2000). Alternatively, other authors favour the adoption of friendship pair interviews or self-scripts (Bayley and Nancarrow, 1998). Friendship pair interviews embody a subset of interviewing techniques where the respondents are recruited

TABLE 2 | IB metrics assessed through laboratory investigations.

	IB metric	Description	Indicator	Reference study
Act of buying	Impulse buying behaviour	Expression of impulsive buying behaviour during the act of purchase	Real unplanned purchase	Vohs and Faber, 2007; De Vries and Fennis, 2019
			Experimental product category chosen	Bossuyt et al., 2017
	Physiological and behavioural response	Individual reactions encompassing individual's central or peripheral nervous system activity, instinctive non-verbal actions or behavioural exteriorisation	Neural cortical and sub-cortical activations	Hubert et al., 2013, 2018
			Decision time	Huang and Kuo, 2012
			Information ocular search patterns	Huang and Kuo, 2012
			Pupil dilation	Serfas et al., 2014
			Ocular fixations count	Khachatryan et al., 2018
			Facial expressions	Weinberg and Gottwald, 1982
			Electrodermal activations	Bossuyt et al., 2017

TABLE 3 | IB metrics assessed through fieldwork observations.

	IB metric	Description	Indicator	Reference study
Act of buying	Impulse buying behaviour	Expression of impulsive buying behaviour during the act of purchase	Proportion of items bought on impulse	Mohan et al., 2013; Bellini et al., 2017; Bellini and Aiolfi, 2019
			Categorical variable ranging from 1 (no/planned purchase) to 3 (impulse purchase)	Beatty and Ferrell, 1998; Sharma et al., 2010
			Number of actual impulse purchases over a given time	Jones et al., 2003; Parguel et al., 2017
			Number of actual purchases in an immersive virtual store	Schnack et al., 2019

as close acquaintances to explore attitudes, motivations, and behaviours in a spontaneous manner. Self-scripts require the respondents to put in writing their experience in a third-person view, thus releasing self-censorship (Bayley and Nancarrow, 1998).

Our results show that qualitative interviews provide insights into broader factors related to individual meanings associated with the phenomenon. For instance, from the interviewee's transcripts it was possible to extrapolate factors such as post-purchase regret or the connexion between unplanned and impulsive purchases (Dittmar and Drury, 2000). Furthermore, from a combination of qualitative interviews with quantitative observations, Dittmar et al. (1995) provide evidence for the relationship between identity-relevant products and IB. As concerns sample size, our results show that interviews relied on smaller samples, ranging from 30 to 46 subjects, thus favouring depth over breadth of analysis.

DISCUSSION

This systematic review underscores that the methods employed to assess IB in consumer behaviour research are various. Therefore, we deem appropriate to set out our discussion with a comparison of the different approaches highlighting their fit to the characteristics of IB. Directions for future research are discussed in the following.

Research Approaches Comparison

The four catalogued approaches imply different specificities in terms of research design, skills and knowledge, data collection methods, context of use, and costs (Cassar and Friedman, 2004; Given, 2008; Nardi, 2018). Each approach also allows investigating IB from a different perspective. For instance, laboratory investigations allow tracking the temporal progression of a purchasing action from the first encounter with a product to the buying decision. Survey research, on the other hand, may discount the sequence of behavioural actions but facilitate delving into the buyer's rationalisation of the purchasing act. On this premise, we claim that the four research approaches might find a proper fit in assessing a specific facet of IB, namely its cognitive, conative, or visceral side.

Self-reports and qualitative interviews provide a significant contribution in assessing the cognitive externalisations of IB. This cognitive facet includes the understanding and interpretation of the phenomenon. Answers provided through self-reports require that respondents must determine their

response through introspection. Accordingly, this process focuses on the rationalisation of behaviour (Nardi, 2018). Self-reports and interviews may prove to be effective in investigating the buyer's justification of determinants and consequences of IB. These include the perception of urges to buy, pre-shopping intentions, representations of future states, or post-purchase dispositions. In other words, self-reports and interviews provide measures of information that cannot be measured directly through observation but demand a narrative framing from the buyer. Furthermore, self-reports and interviews are generally flexible to the context of use, namely they do not require the use of specific measurement instrumentation. Therefore, these approaches can be applied to most research settings that involve an interaction with the participant.

Despite their potential in the assessment of latent constructs, quantitative self-reports and interviews involve an intrinsic risk of responses' reliability. Biases in responses triggered by social desirability, acquiescence in the respondent, or alteration in response recalling, play a central role in IB research. For instance, since IB appears to be often linked to unfavourable consequences or pure irrationality, respondents might be prone to answer in a socially desirable manner (Parboteeah et al., 2009). Researchers need to consider appropriately their research design when questioning IB. To mitigate the biassing effects, specific strategies should be considered. These include the use of social desirability scales, forced-choice items, or the introduction of disincentives to misreport (Nederhof, 1985; Fischer and Fick, 1993).

Behavioural responses are linked to the second facet of IB, namely its conative side. Laboratory investigations and fieldwork observations arguably represent suited research approaches to assess purchasing actions with reference to their rapidity or spontaneity. These approaches imply a direct observation of the purchasing action, thus allowing the monitoring of non-verbal behaviours and their reaction time. The tracking of instinctive behavioural responses paves the way for the assessment of distinctive typologies of impulsivity, including behavioural and process impulsivity. Behavioural impulsivity is manifested as the propensity to make spontaneous purchasing decisions (Koufaris, 2002). Impulsive purchasing behaviours may be evaluated through the amount spent impulsively or the willingness to restrain an impulse (e.g., Vohs and Faber, 2007). Process impulsivity, on the other hand, is manifested as a bounded will to perform a comprehensive evaluation of the product attributes (Pieters and Wedel, 2007). To assess this aspect, information search patterns or behavioural interactions with the purchasing environment may be tracked.

Laboratory investigations by their nature promote significant internal validity, given the possibility of controlling most of the nuisance variables. On the other hand, fieldwork research does not involve any manipulation of environmental variables, thus entailing higher external validity. Accordingly, the choice of the research approach should be guided by the research objective and variables at play. When focussing on the effect of a single modulating variable, investigations carried out in a controlled setting may be favoured. On the contrary, fieldwork observation tends to be better suited to investigating actual scenarios involving a set of complex interactions.

Lastly, with regards to the assessment of the visceral facet of IB, laboratory investigations and fieldwork observation may provide the greatest contribution. Since the visceral facet of IB is related to a sudden emotional charge, the observation of the buyers' responses in real-time is central. The assessment of these sudden alterations in the individual's affective state might be performed through non-verbal responses such as facial expressions and proxemics (e.g., Weinberg and Gottwald, 1982) or through physiological responses (e.g., Bossuyt et al., 2017). The monitoring of visceral responses allows a direct measurement of psychological impulsivity, intended as a sudden feeling, desire, or urge to buy (Rook, 1987; Piron, 1991).

Positing a fit between the four research methods and the three facets of IB, the results of our systematic review highlight two notable patterns. First, we spot a tendency to focus extensively on self-reported measures. The majority of previous studies proves to be limited to surveys aimed at inquiring individual thoughts and contextual evaluations, thus potentially oversighting the implicit mechanisms driving the buying act. Second, we underscore a lack of real-time assessment of IB. Despite little evidence of alternative research methods, common practises in IB research tend to collect data with a time lag between the purchasing act and its measurement. Both elements emphasise that past and current research have focused substantially on the cognitive facet of IB. Instead, the assessment of IB through its conative and visceral facet appears to be still in its infancy. This reliance on cognitive assessments of IB influences both its theoretical understanding and the related practical applications. From the theoretical perspective, this approach may cause a misalignment between the conceptualisation of IB and its actual assessment. Indeed, measurement practises represent a substantial basis for empirically testing theoretical hypotheses and assess consistent knowledge for future research. On the practitioners' side, the issues might affect the reliability of the information which is used as the foundation to deploy marketing actions.

Directions for Future Work

The present review encourages the adoption of a broader perspective in the assessment of IB. We argue that future research should not exclusively gravitate around the cognitive side of IB, but rather it should encompass methods analysing the visceral and conative facets of IB. To overcome the two issues identified (i.e., over-reliance on self-reports and lack of real-time assessment), we posit that current IB research may be complemented with a broader set of investigation methods. We specifically refer to the use of applied psychophysiology tools, namely the analysis of physiological and behavioural responses to delve into IB behaviours.

Physiological analyses are intended to assess the individual's reactions based on responses related to either the central or peripheral nervous system activity. We expect that IB research may be a fertile ground for the application of physiological

analyses, considering the major role of affective charges as well as the rapidity and the powerful behavioural drives that characterise IB. For instance, research might greatly benefit from the assessment of physiological activations in conjunction with atmospheric triggers (e.g., ambient music or lighting condition) to examine the impact of cues that prompt IB. Behavioural analyses represent a parallel approach. We argue that investigations may be broadened by analysing metrics such as the decisional time, gaze behaviour, or vocal expressions during the act of purchase. For instance, the amount of information processed before the purchase might be assessed through decisional time or ocular search patterns. Correlates of impulsivity can be also investigated through behavioural tasks. These include tasks to measure risk propensity or impulse control, such as the Balloon Analogue Risk Task or the Cued Go No-Go Task (Lauriola et al., 2014).

Our argumentation is aligned with previous methodological observations positing that research may benefit from the adoption of complementary methods to self-reports (Scherbaum and Meade, 2013; Bell et al., 2018). Drawing upon this argument, we identify three opportunities for future IB research: theory building and refinement, understanding the role of individual differences, and honing behavioural predictions.

First, theory building and refinement may stem from the understanding of the boundary conditions of the current theories. For instance, extant research often associates affect with a trigger or a state concurrent to the impulsive purchase (Amos et al., 2014). However, the construct of affect is often broadly outlined. Analysing the physiological responses before, during, and after the moment of purchase may shed light on the nature of affective states involved during IB. Psychophysiological tools also allow discerning the temporal evolution of the externalisation of affect and assess how it influences the purchasing process. From this perspective, forthcoming research may find fertile ground in the investigation of the latency time in decision-making, or the role played by cool-down phases. Comparing visceral responses and subjective rationalisations may further clarify their relationships. In particular, future research can benefit not only from the positive correlations between visceral and cognitive responses but from their tensions. Since IB is often characterised by an emotional conflict, insights are expected to emerge from the analysis of discordances between reflective and impulsive responses. Along these lines, prospective investigations may re-examine the categorisations of IB, thus sharpening the classification earlier advanced by Stern (1962).

Second, applied psychophysiology tools may help to understand the role of individual differences, namely why some individuals are more prone to impulse purchases than others. The application of these tools may shed light on the neural structures and physiological responses involved in impulse purchases. They also support the investigation of state-dependent variability. Namely, understanding how different contingent physiological states drive some individuals to purchase impulsively. Along these lines, future research might investigate how temporary states (e.g., stress or fatigue) trigger impulse purchases.

Lastly, applied psychophysiology tools enable gathering additional data useful for improving behavioural predictions. Practitioners may specifically benefit from the enrichment of current multifactorial models (e.g., Prashar et al., 2015) combining self-reports and psychophysiological measures. Predicting the occurrence of online IB has notable marketing implications. For instance, marketers might increase their knowledge about the effectiveness of marketing stimuli such as product placements or promotional campaigns. Moreover, given the relation between IB and product return behaviour (Kang and Johnson, 2009), future research might focus on predicting the occurrence of product returns as a consequence of impulse purchases. The adoption of multimodal research approaches may further shed light on the weight of each facet of IB and highlighting the role of individual and situational factors.

LIMITATIONS

Our results might be subject to certain limitations related to the literature selection process. The systematic search process carried out is dependent on our main query. In our search approach we scanned for documents published in renowned academic journals, hence we intentionally excluded conference papers and books. In doing so we cannot exclude having omitted novel experimental literature and monographs studies. Furthermore, with the decision to exclude studies with psychiatric implications such as compulsive buying behaviours, we have potentially neglected a part of the literature adopting psychophysiological tools. Drawing from related clinical literature, the research approaches based on physiological responses might be enriched to define biomarkers or behavioural indicators related to IB.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

MM and LL conceived and structured the study. MM wrote the first draft and each section of the manuscript. All authors contributed to the article, final revision, and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.687404/full#supplementary-material

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

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CONCEPTUAL ANALYSIS
published: 13 July 2021
doi: 10.3389/fpsyg.2021.672217

Brain-Adjusted Relational Leadership: A Social-Constructed Consciousness Approach to Leader-Follower Interaction

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *25 February 2021*
Accepted: *02 June 2021*
Published: *13 July 2021*

Citation:
Psychogios A and Dimitriadis N (2021) Brain-Adjusted Relational Leadership: A Social-Constructed Consciousness Approach to Leader-Follower Interaction. Front. Psychol. 12:672217. doi: 10.3389/fpsyg.2021.672217

Relationship-based approaches to leadership represent one of the fastest-growing leadership fields and help us to understand better organizational leadership. Relation-based approaches emphasize the relationship and interaction between the leader and the follower. The emphasis is placed on the way that they interact and influence each other at attaining mutual goals. It is known that leaders are linked to followers and *vice versa* in a sense of responding to other's needs toward the achievement of mutual goals. Leaders and followers are an essential part of this social process implying that they are losing their traditional identity rooted in the formal organizational structure (manager-subordinate) and become inseparable actors of a co-constructing process of leadership. What is less known though is the way that leadership actors are linked to each other and in particular how they try to understand how to do that in the workplace. What is even less understood is the importance and role of consciousness in this relationship. Especially since consciousness appears to be both a fundamental and a very elusive element in human relations. Therefore, this paper conceptually explores the concept of consciousness within the context of the social brain theory to argue that leadership actors need to rethink their approach to individuality and focus on mutually dependent relations with each other. This paper contributes to the field of Neuro-management by introducing the concept of *Homo Relationalis*. In this respect, we suggest that leadership is not just a socially constructed element but also a social brain constructed phenomenon that requires an understanding of the human brain as a social organ. We further recommend a new approach of applying cognitive style analysis to capture the duality of leader/follower in the same person, following the self-illusion theory. Finally, we conclude that we need to further emphasize a *social brain-adjusted relational leadership approach* and we introduce two new cognitive styles that can help capture the essence of it.

Keywords: relational leadership, neuroscience, leader-follower, consciousness, self-awareness, cognitive styles, social-brain theory

INTRODUCTION

Relationship-based approaches to leadership represent one of the fastest-growing leadership fields and help us understanding better organizational leadership (Dihn et al., 2014). Relation-based approaches emphasize the relationship, and thus interaction, between the leader and the follower, rather than focusing on leader or follower's characteristics and attitudes. In other words, the emphasis is placed on the way that the two human aspects of the leadership phenomenon interact and influence each other toward attaining mutual goals (Erdogan and Liden, 2002). It is known that leaders are linked to followers and *vice versa* in a sense of responding to each other's needs (Simons et al., 2011). The process of their interaction along with the result of their interaction comprise the wholeness of leadership. Viewing leadership as a relational process means that there is a mutual social influence "through which emergent coordination (i.e., evolving social order) and change (e.g., new values, attitudes, approaches, behaviors, and ideologies) are constructed and produced" (Uhl-Bien, 2006, p. 655). Leaders and followers are essential parts of this social process implying that in a relational mode of understanding leadership, they are losing their traditional identity that is rooted in the formal organizational structure (manager-subordinate) and become inseparable parts of a co-constructing process of leadership. They become, according to our view, leadership actors[1].

What is less known is the way that leadership actors are linked to each other and in particular how they try to understand how to do that in the workplace. What is even less understood is the importance and the role of consciousness in this relationship. Especially since consciousness appears to be both a fundamental and a very elusive element in human relations. Therefore, this paper explores the concept of consciousness within the context of the social brain theory to argue that leadership actors need to revise their approach to individuality and focus on mutually dependent relations. Furthermore, we introduce the concept of *Homo Relationalis* that should replace the dominant figure of *Homo Economicus*. In this respect, we suggest that leadership is not just a socially constructed element, but also a social brain constructed phenomenon that requires an understanding of the human brain as a social organ. We further recommend a new approach of applying cognitive style analysis to capture the duality of leader/follower in the same person, following the self-illusion theory.

In order to reach the aforementioned arguments, we have employed a research approach called the Convergence Method of Evidence (CME). This method, not unlike the investigative work of detectives, strives to explain phenomena by drawing insights from diverse fields simultaneously and from multiple inquiry lines, instead of utilizing more straightforward and single-path science methods (Shermer, 2011). CME has also been called abduction, since it is neither induction nor deduction. In abduction, or inference to the best explanation, "we take the all of our background knowledge about how the word works and decide what possible explanation provides the best account of all the facts we have" (Carroll, 2016, p. 41). By combining diverse but relevant theories and research from neuroscience, evolutionary biology, anthropology, psychology, and leadership, we were able to construct a new approach in understanding leader-follower relations and to develop the neuroscience-based model we suggest.

Following the CME method, the paper is organized in six sections. In the first one, we try to review the main arguments coming from relational leadership schools and how they are associated with brain science. In the second and third sections, we explore consciousness arguing that it is linked more to a collective brain and not to an individual one. In the fourth section, we bring on the discussion social brain theory that also links relational approaches to leadership with neuroscience. In the fifth section, we show that although social consciousness and social brain theory can show us the way toward relational leadership, the evolution of leadership and leadership relations were based on a bounded view of human relations driven by the *Homo Economicous* archetype that emphasize our egoistic selves. In the last section, we summarize our main arguments and we introduce two new cognitive styles that can help capture the essence of social brain-adjusted relational leadership.

RELATIONAL LEADERSHIP ON BOARD

The traditional leadership theories attempted to approach and understand leadership as an individual feature that consists of many cognitive aspects. The focus was on the individual that acts as a leader and his/her traits, behaviors, and styles. In other words, leadership traditionally is viewed and explored as an isolated phenomenon that is based on the main actor, the leader, and his/her behavior formulated by his/her experience and knowledge. As Cunliffe and Eriksen (2011) argue, traditional leadership theories were based on the "*periphery* and *content* aspects of leadership" (p. 1428) not the actual sense of leadership. These approaches ignored that leadership is a social phenomenon that takes place in a social context and it is highly formulated on a continuous basis from people's actions and interactions. In this paper, we follow a different approach to leadership that is not related only to the individual level of analysis, but mainly to a dyadic and group analysis, where leadership is a part of social context full of interactions (Dionne et al., 2014). The context includes the dyadic level of analysis, but expands on the group and organizational level as well (Yammarino et al., 2005). This multilevel context of interaction includes two main leadership actors: the leader and the follower(s) (Schriesheim et al., 2001). The actors cannot be seen independently of the context that they participate as well as they cannot be seen independently of the people that relate with (Dimitriadis and Psychogios, 2020). For example a recent study found that the perceptions of leadership as well as aspiration for leadership are influenced by both cultural and socioeconomic elements (Hoyland et al., 2021). In other words, leadership occurs within the process of relating with each other, aiming in doing things in a non-static, but dynamic and continuously evolving context. In this respect, a school of thought

[1]In this paper we suggest the term *leadership actors* referring to both leaders and followers that co-create and define leadership as a relational process.

has been developed arguing that we need to understand the nature of leadership as a relational process (Graen and Uhl-Bien, 1995; Liden et al., 1997; Murrell, 1997; Erdogan and Liden, 2002; Uhl-Bien, 2003; Dihn et al., 2014) giving birth to the *Relational Leadership Theory* (Uhl-Bien, 2006).

Relational leadership does not primarily refer to behaviors of leaders that are relationship-oriented emphasizing on compassion, support, trust, and high quality work relations (Graen and Uhl-Bien, 1995; Lipman-Blumen, 1996; Brower et al., 2000; Uhl-Bien et al., 2000). Although, we recognize the importance of these aspects in relation to consciousness and social brain, relational leadership can be understood as a social construction process within complex collective entities (organizations) and through connections and interdependences of their members (Hosking et al., 1995; Bradbury and Lichtenstein, 2000; Psychogios and Garev, 2012). The relational school argues that leadership is understood as a continuous and evolving reality within the process of organizing and occurs in interdependent relationships (Uhl-Bien, 2006). Therefore, leadership as a relational process has to be explored in the context of ongoing dynamic relations (Holmberg, 2000).

However, there are different approaches of how relational processes formulate organizational leadership realities emphasizing on dialogue and conversation, relational dynamics and creation of interactive processes (Cunliffe, 2001; Vine et al., 2008; Ness, 2009). For example, leadership is seen as a relational dialogue among organizational members, whose interaction and engagement constructs everyday organizational realities (Drath, 2001). This view of leadership is not related to a person's dominance and power of influence as traditional leadership approaches claim. Leadership is related to the way that people experience daily events and making judgments in the moment of their interactions with others in organizations about these events (Cunliffe and Eriksen, 2011; Antonacopoulou and Psychogios, 2015). With this in mind, leadership is a shared responsibility and social act rather than an individual action based on personal behaviors and characteristics (Murrell, 1997). In short, leadership is always a process of relating, and relating is a constructive, ongoing, and dynamic process of meaning making (Uhl-Bien and Ospina, 2012). In this respect, the present paper adopts a relational definition of leadership where leadership is viewed as a *never-ending meaning-making story* that is located in the ways that organizational members act and interact with each other, attempting to influence organizational understandings and produce outcomes (Barge and Fairhurst, 2008).

However, what it is less known and comprehensive from the relational approach to leadership is associated with the "how" of leadership process. It seems that there is a missing link regarding the ways that leadership is constructed as a meaning making process. We suggest that this gap can be covered if we also take into account other approaches of understanding social connection that can be found in brain science. In particular, we argue that leadership as a relational process of meaning making that is taking place through endless influential interactions in a specific context, requires the brain awareness of leadership actors (leaders and followers). In other words, relational leadership approach can be seen and understood better if we engage neuroscientific approaches.

In the next sections, we utilize on consciousness approaches and social brain theory to demonstrate our arguments. We argue that consciousness helps us to be aware of our own subjective experience of events and processes, hence relational leadership experiences as described above. This in turn, can facilitate the leadership process itself. In addition, by putting on board social brain theory, we support the view that our brains are better fit to relational experiences and therefore relational leadership as such rather than traditional (hierarchical) leadership formalities. We conclude by suggesting the need for a brain-adjusted relational approach to leadership.

UNDERSTANDING THE NATURE OF CONSCIOUSNESS

Within the few scientific debates attracting major attention from media and the public imagination, consciousness holds a prominent position. Article titles such as "Why can't the world's greatest minds solve the mystery of consciousness?" in 2015 on The Guardian (Burkeman, 2015) and "World's Smartest Physicist Thinks Science Can't Crack Consciousness" in 2016 on Scientific American (Horgan, 2016) portray the levels of fascination, but also sensationalism, that the concept of consciousness attracts. Media coverage aside, understanding consciousness, and its role in human relations, might hold the key to upgrading the analysis and comprehension of relational leadership within organizations.

The main challenge of studying consciousness can be summarized in the question: can we ever fully reveal its purpose? This question has been dubbed as the Hard Problem of consciousness (Chalmers, 1995) and has been the leading conundrum for many in search of decoding consciousness. Chalmers (1995), separated the easy problems (can be solved through computational or neural mechanisms) and the hard problems (cannot be solved by computational or neural mechanisms) of studying consciousness. However, the actual hard problem of consciousness is human *experience* since "…we have no good explanation of why and how it so arises." (Chalmers, 1995, p. 5), In addition, the soft part of this problem is about studying neural and other biological processes that are responsible for capturing stimuli, focusing our attention, controlling our behavior and integrating information cognitively or in general, various functions and abilities (Chalmers, 1995) formulating experiences. The hard part of it goes beyond function and is about subjectivity of experience: the fact that those functions could be done without being necessarily aware of them as we do, but we are.

The above approach of consciousness is a continuation of a number of philosophers' argumentation since classical antiquity and especially ancient Greece, who separated between the physical and inner worlds (Phillips et al., 2014). Talking either about *psyche* (soul) or about *nous* (mind) ancient philosophers were intrigued by subjective awareness and the fact that consciousness existed seemingly in separation from nature. These two worlds, nature and thought, body and mind, or more

recently, brain and mind, has been called Dualism and it is central to the debate on consciousness (Crane and Patterson, 2012). This Cartesian substance dualism, suggests "the mind and the body as two fundamental different "things," equally real and independent of each other…" (Grankvist et al., 2016, p. 1). In other words, according to Chalmers (1995) the dualistic approach of consciousness is about two main questions: *Why we are aware of our own subjective experience* (Hard Problem) and *How are we aware of our own subjective experiences* (Soft Problem). Although this approach does coincide with the exact nature on dualism and despite the fact that there are more dualisms (Phillips et al., 2014), Dualism itself is not universally accepted.

We argue (as many others do) that rejecting dualism might be the fastest way of solving the hard problem of consciousness focusing on the real one, which is the soft problem (Dehaene, 2014). The 'Divide and Conquer' method of modern Dualism needs to be abandoned (Dennett, 1996) if we are to produce meaningful and useful insights of consciousness, particularly for understanding the process of leadership. This is because it is the interplay of the why and how that makes consciousness so central for the relational approach of leadership process in organizations. As Seth elegantly puts it 2016: "But there is an alternative [to the hard and soft problems], which I like to call the *real problem*: how to account for the various properties of consciousness in terms of biological mechanisms; without pretending it doesn't exist (easy problem) and without worrying too much about explaining its existence in the first place (hard problem)."

SOCIAL CONSTRUCTED CONSCIOUSNESS AND SELF AWARENESS

The difficulty in explaining the "Why" of consciousness might lie in the extreme importance that the western world is putting on individuality. The western notion of self has been found to be significantly more individualistic and ego-centric than in other cultures and this has a considerable impact on the subjective experience of westerners, including on their cognition and emotions (Markus and Kitayama, 1991). This acute focus on the individual and on the value of a single person as opposed to wider social units. This individualist approach, laser-focusing on the person's interests rather on communities or the multidimensional bonds within societies, is emerged from the concept of what has been called the *Homo Economicus* view of the human kind. *Homo Economicus* is an individualistic conception of humanity, void of any social dimension, which considers as natural law that the self-interest of one person is the interest of all people, leading to an ultra-egocentric model of decision making and behavior (Pesch, 2002). Actually, the *Homo Economicus* concept can be also found in traditional leadership studies, and it is consistent with a positivistic epistemology and a Cartesian dogma of a clear distinction between mind and nature (Bradbury and Lichtenstein, 2000). It assumes that individuals have a "knowing mind," as well as that they have access to the contents of their mind (Uhl-Bien, 2006) that they can control (Hosking et al., 1995).

Dipped into neoclassical economic thinking and, most paradoxically, bound by an extreme passion for rational decision-making that always aims to maximize results and minimize costs, the *Homo Economicus* model of humanity is fading away: new models such as the *Homo Reciprocans*, the *Homo Sociologicus*, and the *Homo Socioeconomicus* have emerged as an effort to understand better the complex interrelations between people (O'Boyle, 2007). In a similar vein, we propose the term *Homo Relationalis* to show that it is not the individuals as single agents, isolated into an egoistic mind driven by rational self-interest that can help us improve our understanding of socioeconomic interaction. But it is the relational aspects (interconnectivity, interrelatedness, and interaction) between us (*Homo Relationalis*) that needs to be factored in, if we want to explain and further understand the leadership process.

Individuality, self-interest, ego-centricity, and ultra-rationality have been the guiding forces that seem to have shaped, and still shape, our approach to consciousness. If we continue to look at consciousness as a mechanism that creates subjective, thus individual, experiences then we might never understand its value and purpose. However, if we look at consciousness from a more socio-centric and relational view of humanity, taking into account the vital role of interdependency, we will probably start unraveling its true nature faster and deeper than ever before, thus solving the real problem of consciousness.

The main problem of consciousness within the *Homo Economicus* view is that since consciousness, is responsible for our subjective/individualistic experience and for our self-centered, ego-driven decision-making and behavior, then what would happen if those two exact processes were found not to be depending on conscious thinking? What, then, would consciousness be for? Our own personal survival or something else? According to Halligan and Oakley (2015) the role of consciousness seems to be linked to the function of the brain. For example, "muscles and brain areas prepare for an action, such as a reaching out for an object, before we are even aware of our intention to make that movement… consciousness simply occurs too late to affect the outcomes of the mental processes" (Halligan and Oakley, 2015, p. 26). Latest research identified the gap between the brain's unconscious preparedness for action and the conscious awareness of the action to 11 s (Koenig-Robert and Pearson, 2019). The fact that our brains prepare to take a decision much earlier than when our consciousness kicks in, brings down the self-interest foundation of the *Homo Economicus*. In addition, it gives rise to a more collective approach claiming that the sense of self comes from "our unconscious mind, and provides an evolutionary advantage that developed for the benefit of the social group, not the individual" (ibid, p. 26).

We argue that our unconscious mind broadcasts all info and decisions to our consciousness that then creates an individual construct necessary for developing strategies of adaptation in the real world. Strategies such as predicting behaviors of others, disseminating selected information and being able to adjust attitudes in relation to various on external stimuli. This means that consciousness is an emergent product of our unconscious part of the brain in order to assist us in adapting to, and interacting with, our peers in order to evolve together

as a group not as individuals. We call this as a *relational approach to consciousness*. This approach captures vividly the emerging strong argument for consciousness as an evolutionary advantage (Mercier and Sperber, 2011). The importance of human communication for the species survival and growth, the ability to develop individual, conscious thoughts is for persuasion purposes and not for ego-centric decision making. Its role is inherently social.

The evolutionary advantage of a collaborative, relational, and socially adaptive consciousness has been found to hold true from other scientific disciplines as well. Evolutionary anthropology, primatology, and archeology have discovered that *homo sapiens sapiens'*, our species', unique ability to form multilayered social relations and to collaborate within highly complex and coordinated group activities with genetically unrelated individuals makes the single most important difference in species survival. Marean (2015), argues that homo sapiens' extraordinary ability to cooperate, what he has called *hyperprosociality,* which to him is not a learned tendency but a genetically encoded trait, was what helped our species dominate against other related species, such as the Neanderthals. Although cooperation can also be observed in primate species, our unique ability to collaborate in large, well-organized groups by employing a complex morality competence based on reputation and punishment was what gave the edge to humankind (De Waal, 2014). Last but not least, psychology is also revising some of its long-held beliefs on individuality and consciousness toward a more socially oriented approach. One of the most cited tests for studying self-consciousness, especially in the developmental process, is the sticker and mirror test, or otherwise called the mirror self-recognition test. In an early study Gallup (1970) measured self-awareness in non-human species and compare those to humans. Apart from humans very few other species pass the test proving that self-awareness is a function of advanced cerebral processes. Rochat (2009) conducted a similar study in non-western societies with surprising results. Instead of kids reaching for their faces, in many instances, kids were just perplexed of what they should be doing with such an unexpected situation. In particular, out of 104 kids in a Kenyan study only two removed the sticker while the rest stayed confused. Recognizing ourselves in the mirror is not about individuality, about 'us against the world' or about finding our unique personal place in this world (Rochat, 2009). It is instead about active social engagement and formulating images of ourselves based on what others think of us. It is an outside-in test and not the other way around.

These scientific developments, pointing to a socially driven sense of self, have led many in psychology to claim that the sense of a concrete self is an illusion (Hood, 2012). In other words, our self-awareness is a fluid concept dependent on our surroundings, constantly shaped and reshaped by it. As Hohwy and Michael (2017) argue, "social interaction and cultural learning [are] key elements in the dynamic process of shaping one's self through action and interaction," signifying the importance of the *embodied self* as a key approach in revising what it means to be us. This notion seem to be at the core of relational leadership. Many relational leadership studies argue that we are aware of ourselves as leadership actors (leaders and/or followers) based on a relational process with others. Lührmann and Eberl (2007) argue that leadership identity is co-constructed in the process of interaction between the leader and the follower. Similarly, Sluss and Ashforth (2007) claim that the role-based identities of a leader and a follower interactively "influence the [leadership] relational identity such that the [leadership] relational identity is more than the sum of its parts" (p. 13). Moreover, a follower's self-awareness is affected by leadership process itself, contemplating the effects on follower's attitudes toward leadership (Van Knippenberg et al., 2004). In other words, followers' self-conception in the leadership process is formulating in a dynamic way within the process and influenced by it. Therefore, leadership actors through the leadership process co-create a relational leadership identity.

In conclusion, adopting a more social and interpersonal view of consciousness, self-awareness, and evolution has a cascading effect on how we view our personal place in life and of course ourselves as leadership actors. First, if the human mind is not all about ourselves then consciousness is an inherent brain phenomenon that allows us to understand, relate, and interact with those around us appropriately in order to achieve various types of goals together. Second, if we are not as individuals, self-interest obsessed and ultra-rational as the *Homo Economicus* view claims that we are, then the way we set our minds to work with others should be more open, assertive and collaborative than before. Above all, our consciousness emerges unexpectedly, not as the pinnacle of human cognition and of our place in the universe, but as a product of our brains, an illusion even, that helps us create and respond to dynamic social environments and move forward more collectively as humans, professionals, leaders, and followers than individually. But in order for this to happen, we needed the right type of a brain. A "social" brain to be exact. We argue that our brain is mainly a social organ that emphasizes connecting, interacting, trusting, and cooperating, and that this is also confirmed by the evolution of human kind (Dimitriadis and Psychogios, 2020). The idea of relational leadership is based on the same foundations. We argue that as leadership actors we connect to each other in endless, dynamic, interrelated ways in various contexts that affect various outcomes. Therefore, a social brain is an essential part of relational leadership. Leadership is not just a socially constructed, but a social brain constructed process.

SOCIAL BRAIN THEORY AND LEADERSHIP

If you ask someone for their opinion on the species that show the highest level of collaboration between their members, the typical answer that you will receive is: bees and ants. Bees' and ants' ability to collaborate within their communities harmoniously and relentlessly attracts the attention of the public. Nevertheless, the admiration of bees and ants as the ultimate cooperative machines is based on a fundamental misconception. Actually, those species do not have the decision power to choose collaboration or competition, but are directed by chemicals to collaboration (Gamble et al., 2014). In this chemically-induced "tyranny" of

co-working, those species are born to cooperate with specific members of their community and for specific reasons. In an analogy to human societies, organizations would look more like totalitarian systems or like Huxley (1998) put it, like highly structured society. Actually, not counting for humans as highly collaborative species and impulsively choosing bees and ants reveals the damage done by the *Homo Economicus* mindset that focuses exclusively on competitive struggle, self-interest, and isolative individuality. Looking at the evolution of *Homo Sapiens Sapiens* in comparison with other species, and studying brain size in relation to group size, has led to the breakthrough theory of the Social Brain. This theory suggests that socializing, collaborating and co-existing in communities depends on brain size, especially frontal lobe cortical areas (Dunbar, 1998). Humans have a disproportionally big cortex/body ratio and this allows them to form larger groups with complex relations. It can be argued that, according to the Social Brain theory, higher neuro-complexity leads to higher social-complexity. Dunbar (1998) is actually famous for his optimum numbers of various social groups to have close ties between their members—which is 5, 15, 50, and 150 people depending on the closeness of the relationships-. This was found to hold true even in our highly networked era dominated by the internet and social media (Gamble et al., 2014).

The human social brain is able to behave in extraordinary ways. Based on a more complex cortex humans have the ability to reciprocate, collaborate, empathize, trust, form intelligent analysis of social situations, but also deceive and fight more cleverly than other species (Dunbar, 1998). Unfortunately, it is the latter group of those social behaviors that initially attracted many scientists who, by observing children's ability to get what they wanted from their parents, labeled these abilities as Machiavellian[2]. Again, applying a typical *Homo Economicus* mindset, people choose to see manipulation, social deception, and trickery in human children's behavior instead of social cohesion, social intelligence, and social co-existence. This narrowest of views though has been later revised to include all the socially positive behaviors creating a more realistic picture of the social brain's behavioral aspects. Interactivity, interdependence, and mutual understanding are core functions of the social brain since a very early age, leading to healthy development of the human mind as we grow and operate in complex human societies (Hood, 2012).

Two key components of the social brain theory is that first, brain processing capacity determines breadth of social relations and second, that the human kind has a unique ability to understand intentionality, in a much higher level than any other species. Concerning the first, Gamble et al. (2014) observed that cognitive load, the brain's ability to process information, is responsible for the number of people we can associate with in different social setting. Since with every new acquaintance our brain will have to process new information, and even more information for keeping regularly in touch with this new person, our brain's processing capacity will ultimately determine the ability to maintain that relation. Spunt and Lieberman (2013) have found that when cognitive load increases, our automatic mentalizing capacity, our ability to understand and connect to others, drops drastically. Thus, relationship building becomes harder. Our brain's expanded cognitive load is an actual advantage, when compared to other species, but also a limitation because of the boundaries it sets for further social bonding. Concerning the second, unlocking each others' intentionality is a building block of social interaction and since humans can manage up to six orders of intentionality, we are uniquely champions in the animal kingdom (Gamble et al., 2014).

Our intentionality-decoding skills are so advanced when compared with other species that they alone have been deemed enough to explain the Why of consciousness. Graziano (2013) suggests that we have consciousness in order to detect the consciousness of other people and thus to be able to make assumptions about their behavior. The Social Brain theory further supports the relational answer to the "Why" question (hard problem) of consciousness. The evolved human brain is set for dynamic and complex relations that are made possible through advanced intention-reading skills unique to our species. Therefore, answering the "Why" of consciousness in this manner leads to important insights into the "How" (soft problem) of consciousness too. Attention Schema Theory (AST) explains the inner-workings of awareness as an attention system that utilizes external and internal stimuli to create subjectivity, preparing the individual to act effectively to various situations (Graziano and Webb, 2015). Under this approach, consciousness is a neuro mechanism through which the brain creates mental models of reality in order to focus where needed the most. These mental models are both created by attention and result in attention. The ultimate aim is to understand other people, understand our own stance, and to respond appropriately. Although AST does not necessarily require a socially-oriented consciousness approach (Rahimian, 2021), it seems to offer an effective integration of two sister phenomena that many believe to be separate within the brain: attention and consciousness (Nani et al., 2019). In a nutshell, Graziano's AST suggests that our brains construct a simplified model of attention, leading to control of attention and creating to a conscious experience that is both internal (awareness of what is happening with us) and external (awareness of what is happening with others) (Wilterson et al., 2020).

The "Why" and the "How" are coming together, bridging the gap between purpose and function, when consciousness is viewed as an evolutionary mechanism of the embodied self that enables humans to navigate effectively and efficiently through dense and multifaceted relations within families, friendships, institutions, communities, and societies. If this is the case, then it would be logical to expect that leadership in modern organizations is guided primarily by principles of empathy, collaborating, caring, and trust. We suggest social brain-constructed relational process of leadership, it is important to understand how cognitive styles can help us rethink the leader-follower dual relationship.

[2]This characterization relates to the 16th century book The Prince by Niccolo Machiavelli (2011) which has become synonymous to calculative manipulation, according to Thesaurus.com (2021).

COGNITIVE STYLES AND LEADERSHIP/FOLLOWERSHIP DUALITY

In order to understand further the brain aspects of leadership actors, we argue that we need to take a step back, exploring through brain science the leadership-followership duality. Therefore, by focusing on consciousness, self-illusions and cognitive styles it is important to open the research agenda for further understanding of the self-dyadic relationship (leader-follower) that consist the basis of the social brain-constructed relational leadership.

The scientific debate on the evolution and function of consciousness has had intriguing side-effects on other topics, most notably on the concept of the self. The *Homo Economicus* mindset applied to consciousness as the epitome of our individuality, suggests that humans have a strong grip over their self, which they understand and control (Pesch, 2002). Most importantly, people have one, solid self, or personality, which can be captured using quantitative tools like surveys. The problem with this approach is that it does not take into account significant findings from neuroscience and other brain-related sciences pointing to a discrepancy of what we think about ourselves and what is actually happening. This discrepancy, in relation to the concept of the self, has been called the Self-Illusion. Hood (2012) explains the sense of authenticity of an essential self within us, that feels true and unified: "[t]his core self… is, however, the illusion" (p. 82).

The phenomenal experience of a subjective reality and the absence of a core self is also discussed in depth by Metzinger (2003) who suggested the Phenomenal Self-Model concept of the Self-Model Theory of Subjectivity. Metzinger (2009) claims that "[t]he phenomenal Ego is not some mysterious thing or little man inside the head but the content of an inner image-namely, the conscious self-model, or PSM. By placing the self-model within the world-model, a center is created. That center is what we experience as ourselves, the Ego" (p. 7). In other words, humans are not in direct contact with either the external nor the internal words, but they do have a representational model that feels unique and real which is much more socially-oriented and socially-derived than expected.

The point to make about the ego, or self, is that it is more of a feeling than a fixed reality. The human brain adapts its reaction in different settings and switches off and on behaviors based on genes, past experiences and social triggers. Although it feels as a continuous and consistent process, the self is an illusion and people's behaviors depend more on adjusting social brain processes than our sense of a solid self. In order to apply this approach to the relational leadership process, cognitive styles need to be discussed.

Different brains show attention and process incoming information in working memory in different ways. The speed and overall efficiency of these constitute what is called cognitive style (Happé and Frith, 2006). In organizational sciences, the concept of cognitive styles was popularized by the Cognitive Styles Index by Allinson and Hayes (1996) which proposed a questionnaire for measuring managers and employees in two variables, analysis vs. intuition, viewed as being distinct cognitive styles. Few years earlier, the Cognitive Flexibility Theory (Spiro, 1988) emerged in pedagogy, to describe efficient learning under challenging conditions. Cognitive flexibility is contrasted to cognitive rigidity when attention and perception models hinder rather than allow for learning and behavioral change (Tchanturia et al., 2004). The concept of cognitive flexibility and rigidity were popularized in the business world by the work of Dweck (2008) on growth vs. fixed mindset (Dimitriadis et al., 2018). Creative styles have also been linked to create thinking, problem-solving and innovation with the distinction of divergent creative cognitive style vs. divergent creative cognitive style (Chen et al., 2015). In leadership-related literature, the majority of work on cognitive styles has been focusing on creative organizational output and leadership (Zhang et al., 2011) rather than on leadership in general, as shown by the wider use of Kirton's adaption-innovation theory (Stum, 2009), which made the distinction between the adaptor cognitive style vs. the innovator cognitive style (Jain and Jeppe Jeppesen, 2013).

Based on the analysis of consciousness as a social tool, and the social brain and self-illusion theories, we recommend a new cognitive style distinction between the person as a leader vs. the same person as a follower (self-dyadic), with both styles being active at the same time. This means that there is a need in leadership studies to adopt a neuroscientific perspective, where the self of a person within an organization changes to fit into a leadership role, the leadership cognitive style vs. the follower role, the follower cognitive style, based on the situation. Since the presence of an authentic, one-dimensional, continuous and rigid core self has been deemed as a subjective feeling rather than a scientific reality, the change between leadership and followership cognitive styles, each with its own attentional and perceptual distinct processes applied even within the same day, but with different people and overall setting. Although still a hypothesis, such a distinction would help leadership theory progress beyond the standard view of a person as either a leader or a follower (both of them leadership actors), unlocking complex processes that might explain better the dynamic reality of multilayered relations within current organizational realities. Such a cognitively driven hypothesis fits also well with AST, which recommends three key cognitive processes present for human consciousness: endogenous control of awareness, exogenous control of awareness, and the resulting experience of a non-physical awareness of personal being (Wilterson et al., 2020).

From an academic perspective, delving into consciousness theories, social brain, and self-related theories, will help us look into the specific mechanisms of awareness, reality, and meaning creation within the context of leadership actors (leader-follower) relations and the leader/follower duality, and thus, develop further the Relational Leadership Theory (Uhl-Bien, 2006). Furthermore, our approach has the potential of contributing to the advancement of Van Vugt (2006) Evolutionary Leadership (EvoL) Theory, which more recently also includes discussions of a follower viewpoint in explaining evolutionary beneficial leadership-related behaviors (Bastardoz and Van Vugt, 2019). EvoL theory explains the way that

leadership is a biological product evolved through physiological, neurological and psychological processes (Vugt, 2018). What we further suggest is that leadership as a biological product is not relational and context free, since it is highly sensitive to social relations that are occur in a specific context. In particular, our approach by combining relational and evolutional approaches to leadership suggests that leadership as a social process itself is rooted in the brains of leaders and followers that are wired and interacting in continuous, endless ways. In other words, the evolution of leadership follows an additional evolving way of interacting through our brain functions and influencing each other.

From a practice perspective, leadership actors will understand better how their own view of reality and the things they focus on influence their relations with other actors as well as how leadership actors' attention models can do the same. At the same time, leadership actors will have a better view of how their leader/follower automatic cognitive styles influence their relations and decisions. This in turn implies that the development of leadership capabilities in organizations should take into account a social brain-constructed relational approach and target the development of leadership not as a set of individual skills, but in contrast as a set of skills that are dynamic, mutually influenced, and co-created in a social context. This approach requires a good understanding of the cognitive styles of leader-follower in one person as we suggest.

DISCUSSION: TOWARD BRAIN-ADJUSTED RELATIONAL LEADERSHIP

Leadership, evolutionarily speaking, is about creating appropriate conditions and trusting relationships for group members to contribute the most they can in the group's mission. These conditions include trust, care, protection, and cohesion as necessary requirements for effective leadership (Brower et al., 2000; Uhl-Bien et al., 2000). Traditionally, the job of a leader was to provide support and safety to group members in order for them to feel liberated enough to perform their tasks in the most creative, passionate, and successful way. This community-oriented approach to leadership was found to be instrumental in how pre-historic tribes lived and survived in harsh environments. Sinek (2011) utilizing a number of sciences, such as neuroscience, evolutionary biology, and anthropology, has convincingly argued that leadership in modern companies should create circles of trust within an organization in order for its members, and the organization itself, to flourish. He claims that the negative image of big business in Western societies is exactly because of the unnatural type of leadership they apply. When leaders look only after their own interests, ignoring the welfare of their employees and the society as a whole, they do not act as our brain expects. We argue that based on the relational aspect of leadership, true leadership actors (leaders/followers) care for each other using their consciousness as a tool for the development of in-group collaboration, interdependence, and trust. These should be the key relational bonds in a continuous process of interaction among organizational members.

However, current evidence, mainly from Western societies, shows something different. The fact that business, as a societal institution, has an unfavorable image within the wider global population is well-documented. The annual Trust Barometer study by Edelman (2020), conducted in 28 countries with more than 34,000 respondents, found that increasingly, people are showing less trust to the businesses-oriented capitalistic system, with almost half of the sample (48%) claiming that the system is not working for them and the second largest group not being sure (34%). In a similar poll by Gallup (2020), only 19% of respondents in the US showed confidence in big businesses compared to 72% for the military and 75% for smaller businesses.

Corporate leadership seems to have gone exactly the opposite way of an anthropological and social brain-based leadership. *Homo Economicus* has turned leadership to a Machiavellian instrument of deceit, manipulation, and self-preservation. Essentially, leadership is turned into something that psychopaths could do uniquely well. A study has found that one out of five CEOs (formal leaders) are psychopaths (Agerholm, 2016). This number, according to the study, is equal to prison populations. This is an alarming finding, having in mind that the percentage in the total population is around 1%. Similar insights can be observed in other domains. Both the empathy deficit, the drop in overall empathy levels (Colvin, 2015), and the increase of narcissism (Twenge and Campbell, 2009) in the wider population have been much publicized (Northwestern, 2006). These intriguing facts seem to contradict the previous analysis in this paper on the nature of consciousness and the human brain as a pro-social organ. If we have been evolving to form dynamic and symbiotic relations, how is it that we are led by psychopaths and at the same time we start losing our hardwired empathic capacities? The answer is in the brain.

Our brain is plastic. New neurons are generated every day, even at a very old age, and old neurons form new connections between themselves, or severe old ones, depending on how much and how often these connections are used. These two processes, namely neuro-generation and the creation of new synapses between neurons, are fundamental to neuroplacticity (Breznitz and Hemingway, 2013). How we use our brains further enhances or weakens our mental abilities. In the case of the brain, this actually means that the software can alter the hardware, something that does not apply to manmade devices such as smartphones and laptops (Dimitriadis and Psychogios, 2020). If the requirement for managers to progress within corporations is to adopt psychopathic attitudes and behaviors, repetition will lead to permanence. Neurons that fire together, wire together (Lowel and Singer, 1992). Over time, by suppressing our empathic neural networks and boosting the narcissistic ones, we reshape our brains to mimic ones with anti-social, misanthropic and ultra-egoistic traits. The more our corporate cultures require psychopathic and narcissistic managers (leaders) the more the brain of employees (followers) will adapt to the situation. Thus, although wired around social brain, leaders and followers choose to utilize more often and with stronger efforts their non-collaborative, non-trusting, non-coexisting style resulting to brains reacting more psychopathically.

If we are to embrace the full scope of our co-operative consciousness and inter-depending social brains, we need to emphasize brain-adjusted relational leadership. A dynamic, co-created type of leadership based on relational ties of all leadership actors (leaders and followers) rather than on obsession with rigid self-interest. A type of leadership that shows a better understanding of the inner-workings and, especially, the purpose of key brain functions. A type of leadership that will bring about trust and collaboration within organizations, and that, ultimately, will unleash the true power of the *Homo Relationalis*.

Without any doubt, more conceptual and, of course, empirical studies are needed within the leadership discipline to establish the exact processes of consciousness in leader-follower relations. Future research should be open to new ways of studding leadership not abandoning the traditional socio-psychological approaches, but introducing new innovative combined methodologies. Leadership studies based on neuroscientific approaches could show the way ahead. For example, a series of leadership studies that will focus on the main biological aspects can be one category. Another category of future studies could be associated with a series of experimental research, not only from the behavioral science point of view, but also from the brain science one. Current neuro-technologies can provide huge opportunities to develop experiments and observe the actual human brain, which in turn can enhance dramatically our ability to understand human relations. For example, using electroencephalogram to measure empathy levels of managers and other professionals within a learning setting (Lambert et al., 2021). In other words, the connection of leadership with neuroscience provides endless opportunities to unlock the hidden forces that affect the way that we relate to each other and of course the way that we are involved in the leadership process. Ultimately, both leaders and followers can improve their relations and achieve more together, in a true collaborative and mutually understanding fashion. They should do this by being more confident for their socially-driven consciousness and embodied self.

AUTHOR'S NOTE

Both authors AP & ND contributed equally to the development of this manuscript. The process of article development was based on our search and work on the field of Neuroscience and Leadership. We first clarified the notions that we want to discuss and then start developing each sections exchanging drafts and corresponding to each other comments and suggestions.

AUTHOR CONTRIBUTIONS

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

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

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frontiers in Psychology

ORIGINAL RESEARCH
published: 27 July 2021
doi: 10.3389/fpsyg.2021.672980

A Sound Prediction: EEG-Based Neural Synchrony Predicts Online Music Streams

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Neuroforecasting predicts population-wide choices based on neural data of individuals and can be used, for example, in neuromarketing to estimate campaign successes. To deliver true value, the brain activity metrics should deliver predictive value above and beyond traditional stated preferences. Evidence from movie trailer research has proposed neural synchrony, which compares the similarity of brain responses across participants and has shown to be a promising tool in neuroforecasting for movie popularity. The music industry might also benefit from these increasingly accurate success predictors, but only one study has been forecasting music popularity, using functional magnetic resonance imaging measures. Current research validates the strength of neural synchrony as a predictive measure for popularity of music, making use of electroencephalogram to capture moment-to-moment neural similarity between respondents while they listen to music. Neural synchrony is demonstrated to be a significant predictor for public appreciation on Spotify 3 weeks and 10 months after the release of the albums, especially when combined with the release of a single. On an individual level, other brain measures were shown to relate to individual subjective likeability ratings, including Frontal Alpha Asymmetry and engagement when combined with the factors artist and single release. Our results show the predictive value of brain activity measures outperforms stated preferences. Especially, neural synchrony carries high predictive value for the popularity on Spotify, providing the music industry with an essential asset for efficient decision making and investments, in addition to other practical implications that include neuromarketing and advertising industries.

Keywords: electroencephalogram, neuromarketing, neuroforecasting, music, neural synchrony, popularity prediction, inter-subject correlation, EEG

OPEN ACCESS

Edited by:
Vincenzo Russo, Università IULM, Italy

Reviewed by:
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Jesús García-Madariaga, Complutense University of Madrid, Spain

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *26 February 2021*
Accepted: *08 June 2021*
Published: *27 July 2021*

Citation:
Leeuwis N, Pistone D, Flick N and van Bommel T (2021) A Sound Prediction: EEG-Based Neural Synchrony Predicts Online Music Streams. Front. Psychol. 12:672980. doi: 10.3389/fpsyg.2021.672980

INTRODUCTION

The application of neuroscience methods to marketing could provide marketeers with new information that is not accessible by conventional marketing research methods (Ariely and Berns, 2010). This line of thought is also called neuromarketing or consumer neuroscience and has expanded tremendously since its discovery (Plassmann et al., 2012; Alvino et al., 2020). Consumers are often unwilling or unable to correctly express their preferences explicitly.

Their stated preferences are biased by the conscious cognitive control over the underlying subconscious response, and consequently, the measurement of explicit choices will not reflect their true preferences (Christoforou et al., 2017).

The lack of introspective capabilities of consumers into their own true preferences is evident when consumers are asked to explicitly reflect on their buying process. For example, the act of reflection actually modified their perception of the choice also called the mere-measurement effect (Morwitz and Fitzsimons, 2004). Other biases that obscure sound decision making include social conformity (Zaki et al., 2011), which causes high variability in subjective ratings. Moreover, Dijksterhuis (2004) showed that distracting consumers, thereby forcing them to make a decision without conscious awareness, resulted in better decisions compared to consciously choosing consumers. To overcome these biases, brain research has been found a fruitful avenue for revealing true preferences.

The line of neuroscientific research where group level interest is predicted from brain activity is called neuroforecasting by Knutson and Genevsky (2018). Their review examines the ability of predicting population-wide choices based on the information of the individual, assuming some choice components may generalize across individuals, and others may not. This paradigm is based on observations that neural representations are – to some extent – modality-general and individual-invariant (Chan et al., 2020) and can therefore be predicted from individual neural responses. Indeed, forecasting the behavior of a large group has been shown to outperform individual stated preferences, values and choices, including viral marketing success (Motoki et al., 2020), the decision to keep watching online videos (Tong et al., 2020), and the success of anti-smoking ads and campaigns (Falk et al., 2012; Schmälzle et al., 2020).

Besides these applications, an impressive body of research is devoted to predicting the success of movies with neuroscience methods (e.g., Hasson et al., 2008b; Dmochowski et al., 2012; Barnett and Cerf, 2017). For example, Boksem and Smidts (2015) found that higher box-office revenue sales of a movie could be forecasted from increased activity at gamma frequencies at fronto-central sites during the viewing of a movie trailer and that the likeability scores on an individual level could be related to an increased electroencephalogram (EEG) activity in the beta range on mid-frontal sites. This demonstrated that even for personal preference, EEG data adds predictive value beyond the respondents' own ratings, stressing the fact that implicit measurements contain unique information that is not accessible with traditional research methods (e.g., self-reports). Their results highlight the added value of EEG on a population-level prediction; box-office revenue predictions improved significantly when the model included EEG data instead of only subjective data.

And this is not the only study where brain activity during exposure to a movie trailer is shown to remarkably increase the accuracy of forecasts of individual and population-wide popularity. Hasson et al. (2008b) proposed the term neurocinematics in order to indicate that the neuroscientific quantitative measurement of viewers' engagement might impact the style of filmmakers and enable the film industry to better assess its products. Now, a decade after the term has been introduced, neurocinematics has matured in the light of numerous studies demonstrating the implicit experience of the audience outperforms traditional methods in revenue prediction.

More interestingly, when we turn to the neural indicators underlying the prediction of market level outcomes, several studies have indicated a comparable measure of brain activity. It has been found that the similarity between viewers' brain activity during the viewing of a movie (trailer) was predictive of levels of attention (Hasson et al., 2008b), emotional arousal (Nummenmaa et al., 2012), engagement (Dmochowski et al., 2012; Chan et al., 2019), social buzz (Dmochowski et al., 2014), future recall (Barnett and Cerf, 2017), memory encoding (Hasson et al., 2008a), personal liking (Chan et al., 2019), or box-office revenues (Barnett and Cerf, 2017; Christoforou et al., 2017). Hasson et al. (2004) were the first to compare the brain responses of one respondent to that of others. By comparing the brain regions across all pairs of respondents, they could identify similar brain responses across the subject pool while they were watching *The Good, the Bad, and the Ugly*. Besides similarity in visual and auditory cortices, frontal and parietal regions also showed similar responses, indicating that the movie also engaged neural patterns associated with narrative and emotional processing.

Where Hasson et al. (2004) referred to the comparison over brain activity over multiple subjects as synchronization, other studies use the terms of alignment (Golland et al., 2017), inter-subject correlation (ISC; Nummenmaa et al., 2012) or between-subject correlation (Haxby et al., 2011), cross-brain correlation (Barnett and Cerf, 2017), neural reliability (Dmochowski et al., 2014), or consistency (Lankinen et al., 2014). In the present research, these terms will be used interchangeably although neural synchrony is preferred.

Schmälzle and Grall (2020) provided an extensive review of research on the similarity of neural responses. Methods that have been employed include magnetoencephalography (MEG; Lankinen et al., 2014) and electroencephalography (EEG; Barnett and Cerf, 2017) but most studies focused on functional magnetic resonance imaging (fMRI; e.g., Hasson et al., 2008b; Dmochowski et al., 2014; Chan et al., 2019). These brain-to-brain similarities can be understood as commonalities between the signal processing of the observers (Schmälzle and Grall, 2020), a collective engagement. This could be explained by the idea that efficient communication requires a successful translation from one individual to another (Hasson et al., 2004), and therefore, similar brain activity should indicate similar experience, needed for efficient communication purposes (Stephens et al., 2010). This is highlighted by studies that deliberately messed up the communication, either by showing unstructured video footage (Dmochowski et al., 2012) or providing manipulated background information (Yeshurun et al., 2017), where indeed neural synchrony was decreased.

Whereas the prediction of movies has gained sufficient research interest, popularity of music has been sparsely evaluated. As it is essential to anticipate the behavior of large audiences to movies for the film industry, so might the music industry profit from forecasting the sales and digital streams of their

albums and singles. The rationale for prediction of movie popularity is provided by the urge to detangle the complex interdependencies of the creative efforts, cast and promotional budgets, as they might all significantly impact the chances of success for a certain movie (Elberse, 2007). However, these arguments do not only hold true for movie trailers; they do also apply to the music industry.

The research into predicting music popularity from brain activity started with a study of Berns et al. (2010) that investigated the effect of social influence on music preference with fMRI. The researchers brought 32 subjects to the laboratory to listen to relatively unknown music that they found on MySpace. The popularity of these songs was established by the number of downloads from MySpace. Two years later, Berns and Moore (2012) heard some of these initial unknown songs suddenly being played on the radio, which led them to reexamine their dataset to investigate whether they could have foreseen which of these songs would become popular. Although they found that the subjective ratings of respondents were not related to the real sales data, they could positively correlate brain activity measured with fMRI within the ventral striatum to the number of units sold. This additional analysis subsequently validated that music popularity can be predicted from brain activity. The line of research into music popularity, however, seems to have ended there.

There have been some studies employing neural synchrony measures on musical experience, e.g., Trost et al. (2015) and Sachs et al. (2020) both studied how the affective processing in fMRI during listening to music is related to subjective ratings of valence, showing that the degree of neural synchrony in brain regions was driven by separate features of music; e.g., synchronized amygdala responses derived from features, such as dissonance, while similar insula responses were derived from acoustic density (Trost et al., 2015). The subjective experience of music was found to relate to neural synchrony in the affective processing circuit (Sachs et al., 2020), and Kaneshiro et al. (2020) showed that basic musical features, such as rhythm and melody, elicited significantly higher neural correlation compared to scrambled musical samples. Additionally, Czepiel et al. (2020) calculated the ISC during three live concerts and showed that tempo was consistently related to increased neural synchrony as well as phrase repetitions, transitional passages, and boundaries.

The application of neural synchronization to music actually makes sense as it is shown that brain waves synchronize with visual and auditory frequencies (e.g., Tyler et al., 1978; Toiviainen et al., 2010). There have been multiple studies investigating neural similarity reactions to music in both fMRI and EEG and even one study that related neural synchrony between the musician and the listener to subjective likeability of the violin concert (Hou et al., 2020). However, besides Berns and Moore (2012) none of them have tied these measures to the general popularity of music.

As is the case with movies, everyone has musical preferences and it provides a perfect integration of narrative and emotion – the aspects that are assessed with neural similarity. In addition, Vogel (2020) estimated that perhaps only 10% of new releases end up making profit for a record label, compensating the financial loss that happens typically on 85% of releases. Labels will encourage excessive production of material without prior knowledge on what will succeed, essentially just diversifying their bets. Digital streaming now accounts for 85% of music industry revenue in the United States (Recording Industry Association of America, 2020). Standing out within this digital music marketplace may be harder compared to traditional CD selling (Simon, 2019; Kaimann et al., 2021). This might urge the need to focus on efficient distribution of promotional budgets even more.

Combining this urge to distribute marketing budgets efficiently with the neural similarity neuroforecasting metric above and the promising results that followed from movie trailer analysis, we propose the use of neural synchrony as a measure of music popularity, making use of EEG to capture moment-to-moment neural similarity between respondents while they listen to music.

Since the study of Berns and Moore (2012) was conducted with fMRI, the validation of EEG in predicting music popularity has yet to be established. The uncomfortable, noisy environment of fMRI measures might have a substantial negative impact on the external validity of choices and the cognition of the respondent, whereas an EEG is wireless, lightweight, and thereby less invasive, additionally less expensive than fMRI and therefore often used in commercial neuromarketing settings. Due to the mobile headset and non-claustrophobic environment, the EEG measurements allow for less obtrusive measurement, and therefore less supposed influence on behavior than fMRI. However, an essential trade-off needs to be made between spatial and temporal resolution. As Dmochowski et al. (2012) state: The fMRI shows if neural activity significantly correlates in response to a common stimulus, but it is unable to show *precisely when* this synchronization occurs. This temporal aspect of EEG is essential as the predictive information in this analysis is carried by the simultaneous timing of responses.

Therefore, the current study aims to further validate the strength of neural synchrony as a predictive measure for popularity of music, which strongly follows from the previous literature. This research fills the void between the fMRI-based music prediction of Berns and Moore (2012) on the one hand and EEG-based neural similarity studies on movie trailers (e.g., Hasson et al., 2008b; Dmochowski et al., 2012; Barnett and Cerf, 2017) on the other hand. Meanwhile, this research shows a new application and validates this approach for a whole new branch that will benefit extensively from successful neuroforecasting. The predictive value of neural synchrony is compared to the sample's stated preferences, and additionally, the neural measures related to these personal likings are also evaluated. Since neural synchrony is frequently interpreted as a measure of emotional engagement of users (e.g., Dmochowski et al., 2012; Chan et al., 2019), an additional intra-subject measure of engagement was included in the study. On the group level, this relationship was hypothesized to be validated, though on an individual level, we expected engagement might be related to likeability since emotional engagement relates to memory encoding and consequently personal purchase decisions (Sebastian, 2014). Another intra-subject metric was proposed

from the neuromarketing literature, namely Frontal Alpha Asymmetry (FAA), which is related to stated pleasantness (Davidson et al., 1990; Vecchiato et al., 2011; Briesemeister et al., 2013) but also enables to predict larger audience popularity (Shestyuk et al., 2019), performing better than subjective ratings to predict sales (Baldo et al., 2015). It was therefore hypothesized that FAA would relate to subjective ratings, and additionally would generalize to the preferences of the larger audience.

Thus, in the present research, neuroforecasting will be evaluated on a group level using neural synchrony, FAA, and engagement. The predictive value will be established above and beyond stated preferences as it is important to compare predictive value to a baseline method. These stated preferences, on the other hand, will also be submitted to neuroforecasting on an individual basis; showing that both FAA and engagement are related to the personal subjective ratings.

MATERIALS AND METHODS

Participants

Thirty-one people participated in the research. The participants were recruited from the Unravel Research participants database from a convenience sample and they received a monetary compensation for their participation. In total, 24 women and seven men between the ages of 19 and 65 (mean ± std. = 27.7 ± 11.6) participated. All the participants were right-handed, reported to have no psychological disorder and signed an informed consent prior to participation. One participant was removed from the data due to an error during data acquisition, which left the sample with 30 participants (mean ± std. = 26.87 ± 10.8).

Stimuli

Fragments of the songs of two albums were used as stimuli during this study. The two albums were the R&B album called "It Was Good Until It Wasn't" by Kehlani and the pop album called "How I'm Feeling Now" by Charli XCX. The albums were chosen because of their convenient release date and because they belong to different music genres. The R&B album contained 13 songs and the pop album contained 11 songs. The songs were sampled by the researcher into 24 s fragments and converted to MP3 format. The fragments were subjectively sampled and contained the most distinctive part of the song, usually the chorus and/or the hook. The stimuli were presented using the iMotions (2019) software.

Experimental Procedure

The research started a few days after the albums' release data to minimize participants' familiarity of the songs. The participants were asked not to drink caffeine-containing beverages prior to the experiment.

At the onset of testing, the participants were seated in front of a computer screen and briefed on the objectives of the study. The participants were told that they would listen to and rate fragments of songs, while their brain activity is measured by an EEG device. Also, the participants were instructed to minimize their head movements in order to prevent EEG-data artifacts.

At the beginning of the experiment, participants were asked to rank the following music genres from 1 ("music genre you like the best") to 6 ("music genre you like the least"): rock, pop, alternative, Hip Hop/rap, jazz/blues, and R&B.

Then, each participant was exposed to 24 song fragments. After each fragment, the participants were asked to rate the fragment based on how much they liked it. The ratings were done by using the 1–5-star scaling system. Each rating began with zero stars, and the participants could not continue without the rating, in order to prevent missing data. The order of the albums was counterbalanced, and the songs were played in a randomized order within the album to prevent order effects.

After listening to and rating all fragments of an album, the participants were asked if they have listened to the album prior to this research. This was done to ensure that the songs were new to every participant. When the experiment was completed, the participants were debriefed and thanked for their participation. The experiment was conducted following the principles outlined in the Declaration of Helsinki.

EEG Acquisition

Brain activity was recorded using the wireless hardware system B-Alert X10 EEG including nine channels following the International 10/20 system of electrode placement (F3, Fz, F4, C3, Cz, C4, P3, POz, and P4). Two electrodes were placed as a reference on the mastoid bones behind both ears. Conductive gel was applied between the scalp and the electrodes, in order to keep the impedance below 40 kΩ. The EEG signals were recorded continuously throughout the experiment at 256 samples per second by the software iMotions (2019). After each participant, the channels were sanitized with alcohol.

Metric Calculations

Preprocessing

Preprocessing of EEG data is performed within the decontamination algorithms of iMotions. Data was Notch filtered at 50 Hz and high-pass Butterworth filtered at 0.1 Hz. Artifacts were automatically removed when the signal amplitude exceeded 400 μV.

Power Spectral Density

The EEG signal is described by the distribution of power into frequency components. Power spectral density (PSD) is calculated by the Fast Fourier transform on all available electrodes. Welch window width was 0.5, and sliding window width is 500 ms, with step size 250 ms. The data was decomposed into frequency bands delta (1–3 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–25 Hz), and gamma (26–40 Hz) by averaging over the included frequencies. The R code to execute this was provided by the iMotions (2019).

Neural Synchrony

Neural synchrony is calculated with a custom R notebook (R Core Team, 2019). The calculation is derived from the previous studies on the inter-subject correlation (ISC) in either fMRI (Hasson et al., 2008a) and EEG studies (Dmochowski et al., 2014; Barnett and Cerf, 2017; Christoforou et al., 2017). Our approach most strongly resembles that of Barnett and Cerf (2017) where pairwise correlations are calculated for every electrode site and time step, which are then averaged to derive a single value of neural similarity. Alpha activity was evaluated in Barnett and Cerf (2017) as it is associated with attention to visual stimuli (Klimesch, 2012) and this frequency band was also employed here. Electrode selection followed the notion of Barnett and Cerf (2017) who showed that C4 and Cz were the most important electrode when predicting weekly ticket sales, thus we decided to select all central electrodes (C3, Cz, and C4).

The PSD over the central electrodes in the alpha band was correlated over time pairwisely for all possible pairs of participants. The steps window width is 1,000 ms, taking 500 ms steps to smoothen the line in qualitative analysis. This indicates that the underlying data results from −750 to +750 ms of the time point concerned. The pairwise correlations of all subjects are absolute and averaged over time. Then this average time series is averaged, resulting in one value per stimulus. The synchrony was multiplied by 100 for interpretability. Thus the equation follows where T is the number of time steps, i.e., the total duration of the musical sample divided by 250 ms, N is the number of subject, and $X_{i[t-2:t+2]}$ defines the matrix of EEG activity of participant i in time $t \pm 500$ ms over the three electrodes:

$$\frac{1}{T}\sum_{t=1}^{T}\frac{1}{N(N-1)}\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}\left|cor\left(X_{i[t-2:t+2]}, X_{j[t-2:t+2]}\right)\right|$$

Frontal Alpha Asymmetry

The PSD for alpha in channel F4 is log transformed, and the log transformed PSD in alpha frequency at channel F3 is subtracted. The R code to execute this was provided by iMotions and works following this equation:

$$\ln\left(PSD_{F4}\right) - \ln\left(PSD_{F3}\right)$$

For each subject, the values are averaged over time. Then for the group comparison, these are aggregated for every stimulus.

Engagement

Before starting the experiment, an alertness and memory profiler (AMP) test is conducted on each participant. This test is provided by ABM (Advanced Brain Monitoring, Inc., Carlsbad, CA). The test consists of three tasks: the three-choice vigilance task, visual psychomotor vigilance task, and auditory psychomotor vigilance task. Each task takes 3 min to complete.

Measures of cognitive states are provided by discriminant function analysis of the EEG signals, which is provided by ABM and runs within iMotions automatically. Based on the EEG recording during the AMP tests, the model provides the probabilities of cognitive states. This study included high engagement (Berka et al., 2007). These commercially available metrics have been shown to be valuable in both marketing and human performance areas (Bernhardt et al., 2019).

Data Analysis

Spotify streams were divided by a million for interpretability. The data was scanned for outliers using their deviation from the mean and multidimensional outliers with a Mahalanobis distance. Outliers deviating more than three standard deviations from the mean were removed from the analysis.

Before correlational analyses were performed, variables were checked on normality using Shapiro-Wilk tests. When both variables were normally distributed, Pearson correlation was implemented. When one of them was not, Kendall correlation coefficients were calculated. Kendall was preferred over Spearman rank since it is considered to be more robust and efficient compared to Spearman correlation (Croux and Dehon, 2010).

Group Level Analysis

Firstly, a correlational analysis was performed in order to establish the relationship between the neurological measurements and Spotify streams. In addition, the relationship between subjective ratings and the number of streams was established, to serve as a baseline.

Multiple comparisons were corrected with Bonferroni correction. The analysis encompasses two dependent variables that are compared on subjective ratings and three neural measures. So in total, eight analyses were done, setting the significance level at 0.006.

General popularity was evaluated by linear regression on the number of streams in Spotify both 3 weeks and 10 months after album release. The assumptions underlying linear regression were tested with a Shapiro-Wilk test for normality of residuals, Breusch-Pagan test checking the assumption of homoscedasticity (constant variance; Zaman, 2000). Linearity assumptions were checked visually.

When the assumptions were not met, natural log transformation was done in order to correct the distribution of the dependent variables, following Dmochwoski et al. (2014) who did the same for heavy-tailed Twitter distributions and Berns and Moore (2012) with the skewed number of music downloads. However, this has consequences regarding the interpretation of the model coefficients (Changyong et al., 2014). Where one would expect that taking the exponent of the coefficient would explain the contribution of that variable, Changyong et al. (2014) argue to transform coefficients by exp. ($b + \sigma^2/2$). To increase interpretability of the results, the log transformation was only applied when this was needed through violated assumptions.

Individual Level Analysis

Since the individual liking is indicated by scores on a five point Likert scale, non-parametric Kendall correlation coefficients were calculated between psychological parameters and likeability scores. Multiple comparisons were corrected with Bonferroni correction. The analysis encompasses subjective ratings and two neural measures. Thus, two correlational analyses were done, setting the significance level at 0.025.

The genre that participants indicated as their personal preference in the first question was divided into a binary state. As most participants in the sample liked pop (n = 16; 53%), the variable was manipulated to a binary factor, indicating whether the person was a fan of pop or something else.

A model was generated by stepwise logistic regression, performed with the MASS package (Venables and Ripley, 2002).

RESULTS

One of the subjects had already listened to one of the included albums but did not show outlying values on any variable, thus was included in the analysis.

Group Level Analysis

Outliers were defined for both the early and late plays. For the early popularity (M = 4.02, SD = 4.08), one outlier exceeded the mean by three standard deviations (streams = 20.06) and was therefore removed from the sample. This left 23 songs in the early plays sample (M = 3.32, SD = 2.29). Streams 10 months after release (M = 12.94, SD = 13.71) also included one outlier exceeding three standard deviations (streams = 59.91), which was another song than the early outlier. Removing this left the late plays sample with 23 songs (M = 10.90, SD = 9.58).

As the sample contained mostly pop fans (n = 16; 53%) and only five R&B fans, the distribution of likeability ratings was examined before continuing the analysis. Remarkably, in subjective ratings the R&B album (M = 2.55, SD = 0.21) outperformed the pop album (M = 2.86, SD = 0.21) significantly [$t(21.43) = -3.67$, p = 0.001]. This is in line with the both early (M_{Pop} = 2.18, SD = 1.43, $M_{R\&B}$ = 5.58, SD = 4.95) and late popularity with the general public, where the two albums differ greatly in favor of the R&B album (M_{Pop} = 5.77, SD = 3.25, $M_{R\&B}$ = 19.0, SD = 16.3) as revealed by Wilcoxon rank test (W_{early} = 23, p = 0.004; W_{late} = 19, p = 0.002). Implicit measures between both albums were significantly different on engagement [$t(19.12) = -2.30$, p = 0.03] and neural synchrony [$t(16.40) = -3.79$, p = 0.002], both showing higher values in the R&B album. Thus, the factor of indicated genre preference was not informative regarding the sample's true preferences.

Correlational Analysis

Normality checks of the dependent variables after the removal of both outliers revealed that both early (W = 0.84, p = 0.002) and late popularity were non-normal distributed (W = 0.70, p < 0.001). While early plays did not cross the threshold set by Hair et al. (2010) for skewness (1.19) or kurtosis (3.41), late plays were both heavy-tailed and asymmetrically distributed ($skew$ = 2.14, $kurt$ = 7.77). Therefore, the later streams had to be log transformed for most analysis to be applicable. The descriptive statistics of all included variables are in **Table 1**.

To start with, it was established that the individual subjective ratings were not related to popularity with the general public. Correlations were not significant for both early (τ = 0.27, p = 0.07) and later Spotify streams (τ = 0.36, p = 0.02).

TABLE 1 | Descriptive statistics of included measures.

Measure	Mean ± SD	Median ± IQR	Normality (W, p)
Early Spotify streams	4.02 ± 4.08	2.94 ± 3.12	W = 0.67, p = <0.001
Late Spotify streams	12.94 ± 13.71	9.34 ± 9.17	W = 0.69, p < 0.001
Subjective ratings	2.72 ± 0.26	2.72 ± 0.38	W = 0.98, p = 0.93
Neural synchrony	29.87 ± 0.60	29.74 ± 0.90	W = 0.94, p = 0.13
Frontal Alpha Asymmetry	0.24 ± 0.60	0.24 ± 0.08	W = 0.98, p = 0.90
Engagement	0.12 ± 0.07	0.10 ± 0.09	W = 0.96, p = 0.42

This indicates that indeed, a simple survey is not sufficiently explaining the popularity with the general population and therefore, a more sophisticated measure must be explored.

For each measure of neural activity, the correlation with popularity was explored. Neural synchrony was not significantly related to early Spotify streams (τ = 0.33, p = 0.03), but it was significantly correlated to late (τ = 0.41, p = 0.006) popularity. FAA and engagement were not significantly related to both measures.

In addition to relations to the popularity of music, variables were also compared with each other. Neural synchrony was expected to relate with engagement due to the previous studies but this was non-significant. The early plays, however, were related to later plays (τ = 0.51, p = 0.0003), indicating that early popularity also may be predictive of later public preference.

Linear Model Predicting Popularity

Linear regression was performed on the data where the outliers were removed. The non-normal distributed dependent variables were log transformed only when this was needed for the assumption of normality of residuals.

Following from the correlation analyses, linear regression models were composed with neural synchrony as the main predictor. This confirmed that the proposed neural synchrony could predict 40.4% of the variance (R^2_{adj} = 0.40, p = 0.0007) within Spotify plays after 3 weeks. Thus with an 1% increase in synchrony, plays are estimated to increase with 2.4 million (b = 2.46, p = 0.0007). The distribution is shown in **Figure 1A**. When the outlier (i.e., the mega-hit) was included, the assumption of normal distributed residuals became violated. The log transformation of early plays was then predicted with 27.93% explained variance (R^2_{adj} = 0.28, p = 0.005), where 1% increase in neuro synchrony resulted in 2.08 million more plays (b = 0.71, p = 0.005).

Even more so, 10 months after the experiment, neural synchrony could still predict 39.3% of the variance (R^2_{adj} = 0.39, p = 0.0008). Please note that these streams were log transformed to meet the assumption of constant variance. This indicates that a 1% increase in synchrony can be expected to show an increase of 2.22 million plays (b = 0.78, p = 0.0008). The distribution is shown in **Figure 1B**. When the outlier (i.e., the mega-hit on the long term) was included in the analysis, the (still log transformed due to non-normality with residuals) number of streams after 10 months could explain 24.44% of the variance (R^2_{adj} = 0.24, p = 0.008), where a 1% increase

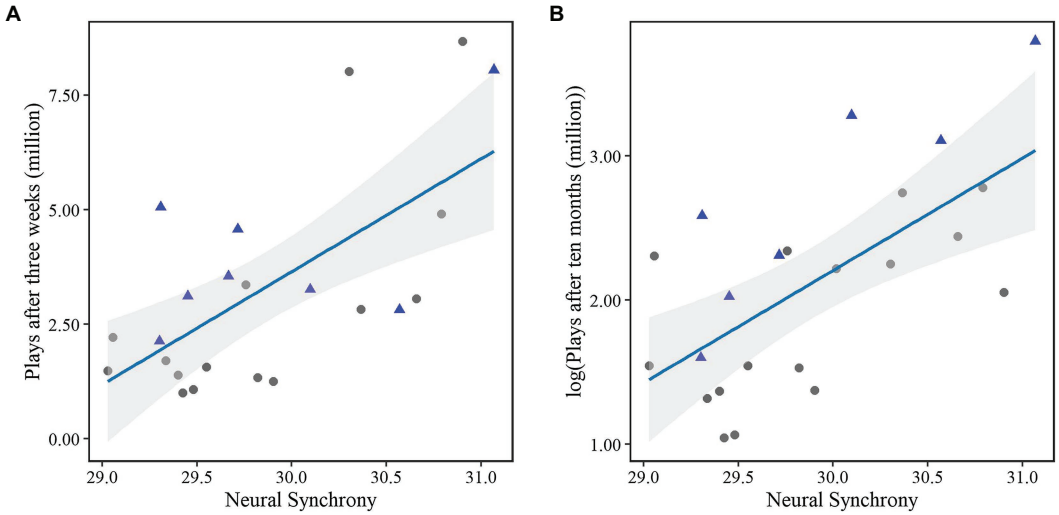

FIGURE 1 | The distribution of singles across neural synchrony and plays **(A)** after either 3 weeks or **(B)** after 10 months log transformed. The blue line indicates the fitted regression line. The gray area indicates the confidence interval. The promotional single releases are indicated by blue triangles.

in neural synchrony would result in 2.13 million more streams (b = 0.72, p = 0.008).

Including the fact that a song was released as a single, was shown to be very influential in the number of streams over time, as for each album the four most streamed songs were all released as a promotional single. Including the release as a single as factor in the model predicting long-term streams, significantly improved the model (F = 13.47, p = 0.002) to an explained variance of 61.91% (R^2_{adj} = 0.62, p < 0.001), with being released as a single increasing the number of plays with 2.16 million (b = 0.75, p = 0.002). Models that included the outlier (i.e., the mega-hit) could explain 55.15% of the variance when the factor single was included (R^2_{adj} = 0.55, p < 0.001). In the previous model, the weights of synchrony and single were almost equal (b_{synch} = 0.75, $b_{singleyes}$ = 0.75), but the model that included the outlier gave more weight to the single release (b = 0.96, p = 0.0006) as compared to synchrony (b = 0.70, p = 0.001). For early streams, the fact that a single was released earlier, did not significantly improve the predictability of the model (F = 1.86, p = 0.19).

To validate the predictive value of EEG measures above and beyond traditional measures, a model was created with stated preferences and the release of a single. For early plays, this model did not meet the assumption of normally distributed residuals (W = 0.88, p = 0.01) and the comparison therefore could not be made. For late plays, the model of personal liking and the release of a single (R^2_{adj} = 0.33, p = 0.007) were significantly improved when neural synchrony was added to the model (c_{20} = 0.62, p < 0.001; F = 16.09, p = 0.0007).

Individual Level Analysis

On an individual level, the popularity is assessed by the Likert scale ratings that the participants gave after hearing the sample. Since this is an ordinal scale, Kendall correlation was employed for all analyses. The likeability scale was correlated to the two neural measures that could be obtained at an individual level: Frontal Alpha Asymmetry and engagement.

FAA showed a significant correlation with likeability scores (τ = 0.10, p = 0.0002). Engagement was not significant.

A model that would be able to indicate popularity on an individual level, was constructed by a stepwise logistic regression was performed using the MASS package, where models were selected based on the Akaike information criterion (AIC). This resulted in the following model: 1.83–1.76*Engagement + 0.69*$Artist_{R\&B}$ + 0.46*$SingleReleased_{yes}$ (AIC = 622.33). Thus, the individual scores increased by a decreased engagement score (b = −1.76, p = 0.0008). The R&B artist performs better (b = 0.69, p = 0.001), and songs that were released as a single are also preferred (b = 0.46, p = 0.04).

DISCUSSION

Although the predictive capabilities of proposed neural synchrony measure were already validated in numerous contexts and outcome measures, its application in predicting music popularity had yet to be established. As several studies used neural synchrony to predict popularity of movies, and several others measured it on music although not for prediction of popularity, our research perfectly fits the void within the current literature by showing that popularity of music could be predicted by neural synchronization 3 weeks after release and was evenly informative 10 months after release. In addition, the strength of this prediction was valuable above and beyond subjective measures of preference and our results thereby show the importance of employing neural measures to eliminate the biases and preferences that are found in subjective reporting. In the following sections, the results will be discussed more thoroughly and the cognitive processes that might steer the consumers toward music listening will be explained.

Group Level Analysis

As noted by Boksem and Smidts (2015), it is important that the predictability of neural measures offers insights above and beyond the traditional methods (e.g., stated preferences). Essential aspects thereof include maximizing the generalizability of measurement to real-world situations and always comparing the new measure to the traditional ones. The body of the literature on neural forecasting showed that subjective measures are biased and that neural measures usually outperform stated preferences (e.g., Motoki et al., 2020; Schmälzle et al., 2020; Tong et al., 2020), although some previous studies showed only a miniscule – albeit significant – additional predictive value of neural measurements over subjective ratings (Dmochowksi et al., 2014; Boksem and Smidts, 2015).

The distinction between likeability within the sample and the whole population is made by Dmochowksi et al. (2014), who reported that neural synchronization was highly predictive of audience-wide ratings, even better than in-sample ratings. Our results indicated the same: Neural synchrony measured within the sample was significantly related to public appreciation on Spotify, however not to subjective likeability scores of the sample itself. The predictive value improved significantly and substantially. This is in line with expectations, as Berns and Moore (2012) also reported that subjective ratings showed no relationship toward the future sales of songs and the previous studies on movie trailers that predicted (box-office) sales of movies (e.g., Barnett and Cerf, 2017; Christoforou et al., 2017). Our results underscore these previous findings and additionally establish that neural similarity is also predictive within the music industry even over several months.

The fact that Spotify streams were predicted 3 weeks and 10 months after their release might seem stunning at first glance. However this robustness also appeared in Christoforou et al. (2017) who could predict the box-office revenues of the premiere based on neural synchronization during the trailer in their sample as well as predicting the actual revenue of the eight weekends following the movie's release. They explain this long-term effect by stating that neural synchrony might signal memory encoding, which is supported by Barnett and Cerf (2017) who found that higher neural similarity during the trailer was indicative of better recall 10 months later. Thus, it is generally accepted that neural synchrony predicts beyond early popularity indications.

Furthermore, early success is likely to have a disproportionately positive influence on chart positions and thus number of streams (Kaimann et al., 2021). Indeed, in our data, we saw a correlation between early and later streams ($\tau = 0.51$, $p = 0.0002$). However, adding the number of early streams to the linear model predicting later streams did not increase its predictive value. Thus, early streams might be strongly indicative of later streams and accordingly show that indeed, it is essential to start off on the right foot when it comes to song releases.

By adding the release of a single as a factor to the model, we incorporated the effects that the promotion of these songs might have had on the number of plays. Studies have been dealing with these external factors differently; most of them do not even mention the fact, whereas Christoforou et al. (2017) divided the box-office revenues by the total budget of the movie in order to account for the variability of marketing capacity and reach. The fact that single release accounted for such an increase in predictability resolves most likely from the fact that the release of a single is associated with a longer time in the charts of digital streaming platforms, which has a powerful sway on the number of streams (Kaimann et al., 2021).

Our data indicates that the combination of higher neural synchronization on the track as well as the release as a single constituted an increased number of plays. Therefore, we argue that a song has to have the "mega-hit potential" and then, single release might be able to increase its popularity. This proneness to become a hit could potentially be estimated by neural similarity measures. As several studies have already indicated that neural synchronization increased with specific aspects of music, such as rhythm, melody, tempo, and phrase repetitions (Czepiel et al., 2020; Kaneshiro et al., 2020), it is agreed that neural similarity identifies emotions at the level of musical features and we hypothesize it will therefore serve as a strong predictor of mega-hit potential.

Additionally, to the effects shown here, the timing of the study adds real value to the results. Most studies on film trailers tested movies that were already released. A little late to the party, as there might have been other factors impacting the consumers' implicit reaction to movie trailers, such as social buzz or promotions. Our study has started on the first day of the album releases, in order to exclude these contributing factors as much as possible. This is also shown by the fact that only one respondent had heard one of the albums already. Therefore, the results could not be influenced by any prior knowledge of either respondents or experimenters and represent therefore a true measure of hit potential.

Several studies have indicated that neural synchrony is linked to collective engagement (Dmochowski et al., 2012; Chan et al., 2019). In the present data, no relationship between intra-subject engagement and inter-subject neural synchrony was found. This could be explained by differentiating definitions and measures of engagement. For example, Dmochowksi et al. (2012) manipulated engagement by showing the same movie clip once in regular order and once scrambled, thereby deteriorating the narrative. Although this is expected to decrease engagement, it is not based on the same definition of engagement incorporated by Berka et al. (2007) and thus, our definition of engagement might be built on other grounds. The use of different neural measures and methods may also contribute to the inconsistent findings. More research is needed to establish the precise relationship between ISC and engagement.

Additionally, engagement and FAA both did not contribute to the prediction of population-wide popularity. Such a relationship was expected for the FAA, as it has predictive value over subjective ratings when it comes to sales (Baldo et al., 2015); however, the hypothesis for individual engagement in this area was more agnostic as there exist no prior studies demonstrating that task engagement predicts popularity. Future research might establish the exact relation between these measures and larger audience popularity.

Individual Level Results

On a group level, other brain measures were not significant to predict general popularity. However, on a more individual level, we found that FAA was related to the subjective likeability ratings and in addition, engagement was an important predictor when combined with the factors artist and single release. Here, we propose why these measures may explain subjective ratings but not the larger audience popularity.

FAA has been established as an indicator of approach-avoidance motivation, increasing with higher stated likeability (Davidson et al., 1990). The metric has been extended to several fields of applied research, including neuromarketing, diagnostics, brain computer interfaces, and therapeutic tools (Briesemeister et al., 2013). Vecchiato et al. (2011) showed that FAA was related to self-reported pleasantness of commercial videoclips, and larger audience popularity was assessed by Shestyuk et al. (2019) showing that FAA during a TV show episode correlated to its viewership and Twitter volume. Especially, Baldo et al. (2015) showed the superiority of FAA over subjective ratings when correlating to the sales of a shoe model. It was therefore hypothesized that FAA would relate to subjective ratings, but also would generalize outside the sample. While we confirmed the first hypothesis, the latter one remains uncertain.

For the engagement measure, we found the same trend: It was not related to larger audience preferences but instead was included in the model predicting stated preferences. This might be explained because the calculation of the engagement metric is done on an individual level – as is the case with FAA. Engagement values are derived from a model that returns probability of high engagement (Berka et al., 2007), specifically tailored to the brain responses of that person due to the benchmarking tests that were done beforehand. This tailoring might decrease the generalizability across subjects thereby making engagement a measure best suited for individual preferences. This hypothesis, however, warrants further investigation. A fruitful avenue for further research in this regard would be to actually manipulate the levels of engagement in order to deepen our understanding of the relationship between individual and group level preferences at various levels of engagement.

Limitations

External factors, such as promotional budget and whether the song has been in charts or shared playlists, have not been included in the study, which might provide a true limitation. Social proof is an important factor in music preference (Berns et al., 2010) as charts are highly valued by consumers (Kaimann et al., 2021); tracks listed in the charts benefit from increased visibility and perceived quality. Moreover, the social sharing component of Spotify and the customizable playlists have further enabled customers to cherry-pick the best outputs from a wide range of music (Kaimann et al., 2021), which may exponentialize popularity on Spotify. In addition, the difference between album sales and Spotify streams is that streams are affected by repeat consumption, while album sales are not (Kaimann et al., 2021). Therefore, these external factors might have an excessive impact on the number of streams and it is extremely difficult to detangle their relations. A future study where these measurements are included might provide better insight in the true drivers of streaming popularity and extend the understanding of its relationship to neural synchrony in doing so.

The prediction of popularity with the larger audience has severe implications for the music industry, enabling them to select which song should be released as a single, which has to get more promotional budgets and whether they will invest in an artist at all. However, we should be cautious in extrapolating the current study's conclusion to the entire music industry, as the downside of our research is the inclusion of only two albums. From an industry's perspective, it would be invaluable to be able to predict the mega-hit from one album, as in real-life situations where the producing artist exchanges ideas with the record label on which songs carry the most hit potential, thus warranting the largest slice out of how the marketing budget is spent across the tracks. To further explore this situation, we evaluated the predictive power of neural synchrony when only one album was included in the dataset. While adding the artist as a factor in the model was not significantly increasing explanatory power, t-tests showed that the number of streams was significantly different between the two albums. The neural synchrony, however, was not significantly different between the albums. Linear models constructed for the prediction of the R&B albums early plays were significant (R_{adj} = 35.99, p = 0.02) where neural synchrony positively impacts the number of streams 3 weeks after album release. However, for the late plays, separate models for both artists were insignificant. Thus, selecting the mega-hit including only one album in the analysis might be less predictive, most likely because of the small dataset that comes with including only one album.

Building a broader database of various songs and their neural synchrony and popularity might therefore diversify the data and thereby increase robustness of predictive power from the data. Since the present study did not test on a whole diversity of artists as was the case with Berns and Moore (2012), the predictive power of EEG-based neural synchrony across multiple artists and diverse genres has still to be established.

Additionally, the distribution of genre preference in our sample might be another limitation, as most participants rated pop (n = 16; 53%) as their favorite genre, and the sample contained only 5 R&B fans (hip hop = 8, rock = 1). As our results showed that the R&B album scored higher on both subjective ratings and neural measures, it was deduced that most likely the participants did not correctly state their preferred genre. Another explanation might be the relative unpopularity of the pop album as its number of streams were also significantly lower. Either way, the distribution of genre preferences within the sample and the genres of the tested albums might have impacted the outcomes. Alluri et al. (2013) showed that ISC varies to different genres of music, related to other brain regions, which provides the urge to explore this aspect even more.

Other limitations with regard to convenience sampling are represented by the unequal gender distribution (7 male and

24 female respondents). Neural synchrony calculations over different groupings, such as gender, can infer different conclusion: Barnett and Cerf (2015) showed that some content in a commercial produced similar responses for both genders, whereas other content had dissimilar effects. Gender effects are also found with music listening as the Spotify algorithm classifies on gender (Werner, 2020). Although the aggregate neural synchrony measure might be modulated by a skewed gender distribution, the relationship with Spotify plays was still established with the sample and this proves generalizability of this measure. For future researches, the sample should be balanced in order to rule out the possible confounding effects of gender distribution.

Location and Frequency of Neural Synchrony

Spatial localization is not the main strength of EEG. Several studies have been conducted in order to establish a more precise definition of locations of neural synchronization during naturalistic stimuli, but so far the results have yet to yield consensus among researchers. Where Barnett and Cerf (2017) and the present research report ISC over alpha frequencies in the central electrodes, beta, and gamma frequencies are also mentioned in Dmochowski et al. (2012) and Christoforou et al. (2017) relating to Boksem and Smidts (2015). The underlying motivations and therefore explanations behind neural synchrony might depend strongly on the included frequencies and localization.

Since we hypothesized the central electrodes within the alpha frequencies, we are basically evaluating the activity patterns of the respondents' mu rhythm, which most likely originates from the somatosensory cortex related to movement and movement preparation (Pfurtscheller and Da Silva, 1999). This sensorimotor synchronization in the alpha band is also called mu suppression, and several studies showed that music listening was related to this activity within motor areas (Chen et al., 2008; Grahn and Rowe, 2009; Ross et al., 2016). The coupling of music listening to motor areas makes sense as the presence of a beat usually causes spontaneous synchronized movements like toe tapping or head nodding (Janata et al., 2012) and beside its prevalence during action performance, mu suppression is also found during observing a movement, and therefore, it might be linked to the mirror neuron system. Although this link still needs robust evidence (Hobson and Bishop, 2017), it might explain the coupling of hearing a beat and synchronizing movement to it – either imaginary or real dancing. And these presumably will be similar across listeners.

Besides these sensorimotor coupling, alpha frequencies are also linked to attention and memory tasks (Klimesch, 2012). Johndro et al. (2019) showed how rhythm increased attention for targets that are presented on-beat as compared to off-beat and this may strengthen memory encoding. Since several studies showed a relation between neural synchrony across participants and attention, this might also provide an explanation for neural similarity results on musical data. The real underlying activity might be further explored.

Previous research predicting music popularity was conducted with fMRI, which has higher spatial resolution compared to EEG. Berns and Moore (2012) found significant results for activation in the ventral striatum/nucleus accumbens (NAcc) during listening to the music samples. The NAcc is anatomically connected to the orbitofrontal cortex (OFC), which was related to purchase decisions as found in the previous studies (Knutson et al., 2007). Especially, listening to non-hits resulted in low-OFC and low-NAcc activations. For personal preference, the linkage was also significant. This connection is usually explained as reward anticipation and correlated to the EEG measure of FAA according to Gorka et al. (2015). However, FAA was not a significant predictor of population-wide popularity in the current study.

Another fMRI study predicting popularity, but for movies, compared the predictability of EEG and fMRI. Dmochowski et al. (2014) found that brain regions in the lateral temporal cortices were highly correlated with EEG neural reliability and an area of parietal cortex including the superior parietal lobule and precuneus. Meanwhile, a significant negative covariation between neural reliability and BOLD activation was found in a region of medial prefrontal cortex that includes the anterior cingulate cortex, as well as the left inferior frontal gyrus.

Other EEG studies (e.g., Boksem and Smidts, 2015; Christoforou et al., 2017) selected electrodes based on the most discriminating spatial filters in the beta and gamma bands. Beta bands showed a mid-frontal cluster focused on AFz, F2, FC1, FCz, and gamma band showed a fronto-central cluster surrounding frontal, fronto-central, and central electrodes (Boksem and Smidts, 2015). These provide a reason for future research to also explore the relation of the (pre-)frontal cortex within EEG-based neural synchrony when listening to music.

In addition to the EEG's reduced spatial resolution compared to fMRI, the current study was conducted with a nine-electrode EEG system, without channels at fronto-central locations, which therefore could not be include in the analysis. However, the validation that this comfortable, relatively affordable and easy-to-apply nine-channel EEG still provides predictive value for popularity, is very important for the end-users in the neuromarketing field. The commercial use is motivated by comfort both for the researcher and respondent, and our results are therefore very valuable for this community.

Future Research

The previous paragraphs most logically deduce the need for a follow-up research where more diversity in musical genres and artists is included. Authors suggest constructing a database wherein the predictive power of neural synchrony over subjective ratings might be further explored and the relationship between them validated on a broader musical library. As noted under the previous limitations, it is important to include as many external variables as possible; such as liking and sharing rates, time in charts, and appearance in public playlists since these have substantial effect on the number of digital streams (Kaimann et al., 2021).

Additionally, the selection of the target audience might be evaluated. The current study engaged in convenience sampling, but it might be that selection on musical taste is preferred. Since neural similarity is a group-level metric, there might

be some respondents disliking a certain genre and consequently downsizing group level neural synchrony. Of course, this can be prevented by checking the pairwise correlation before aggregating them. However, including only fans in the data would in theory lead to a better representation of the target audience. This might be especially valuable in the use case we presented earlier, where record labels want to determine the division of marketing budget across songs on the album – particularly for niche market music. The true increase in predictive value by recruiting the album's corresponding target audience has yet to be established.

Furthermore, Schmälzle et al. (2020) noted that multiple studies have compared neural synchrony values; however, the dynamic fluctuations within a stimulus are rarely understood. Moment-to-moment neural responses might vary across audiences (Barnett and Cerf, 2015), and Dmochowski et al. (2012) also proposed a more integrated look at the peaks within neural synchronization to explain their origin from the naturalistic stimuli. Evaluating moment-to-moment ISC might reveal the underlying processes within the music, such as its relationship to beat, lyrics, or emotional state.

Elaborating on this suggestion, a future study could extend our findings by implementing valence and arousal measures to the data, in order to predict emotional experience during music listening. Especially, since listening to music is usually an emotional experience. Further research on emotions, perspective taking and neural ISC is provided by Jääskeläinen et al. (2020a,b). Classification of emotions across participants can be improved by adding inter-subject correlations to the feature space as shown by Chan et al. (2020) and Haxby et al. (2011) and thus may be an interesting elaboration of the current research.

Additionally, Dmochowski et al. (2012) made the distinction where neural synchrony is defined as an indication of agreement within a group of individuals, conveying the fact that multiple viewers must be experiencing the stimulus similarly, as these are modulated by the content of the stimulus inter-subject correlation (ISC). On the other hand, they defined intra-subject correlation which indicated how reliably a scene elicits a response within the same subject. The neural response varies within and across individuals due to their subjective evaluations and uniqueness of brain structure with each individual, and therefore, it may be interesting to compare our between-participant results also within the participants in order to evaluate their responses to repeated presentation of a musical sample and in addition to establish a more integrated view of the matter. Functional Connectivity measures are widely implemented in music in order to evaluate emotions (e.g., Daly et al., 2014; Naser and Saha, 2021) and would provide a valuable reference point to compare between and within neural similarities.

Practical Implications

As the research is directly related to a real-world problem, the practical implications deserve a proper discussion. While we do encourage the use of neuromarketing tools for prediction of popularity, authors note that subjective ratings might still provide valuable insights and should be considered next to implicit ones.

Since digital streaming now accounts for 85% of music industry revenue in the United States (Recording Industry Association of America, 2020), the contribution of the present study is substantial and of great importance to the music industry. Our results show that the combination of high neural similarity and the release of a single predicts the popularity on Spotify greatly. While it was known that single release significantly increases its digital streaming (Kaimann et al., 2021), the effect thereof may be even improved by choosing the right song to turn into a single. Since the functions and algorithms of digital streaming platforms may easily exponentialize the number of streams as soon as the song is picked up by a chart, early popularity is almost essential for later popularity (Kaimann et al., 2021). This implies that the choice of single has to be right from the beginning, stressing the importance of an accurate prediction. Neural synchrony provides the perfect opportunity to pinpoint the hit potential among a musical database and thereby might assist the music industry in dividing its marketing budgets. Before the release of an album, the record label can value the songs based on their neural synchrony value and in doing so divide the marketing budget properly and choose the highest scoring songs to release as promotional singles.

The findings can also be extended beyond music as neural synchrony is already an established predictor for movie liking (Chan et al., 2019) and revenues (Barnett and Cerf, 2017; Christoforou et al., 2017). Besides entertainment, Dmochowski et al. (2014) and Chan et al. (2019) showed that advertising industries might also benefit from neural synchrony as a neuromarketing metric. In advertising, the success of a commercial is largely dependent on either brand image (i.e., brand recall) or motivation to buy. Besides commercial use, health messages, for example, regarding excessive alcohol use can also benefit from predicting their impact with neural synchrony (Imhof et al., 2020). Thus, the application of this metric in advertising would be valuable.

Last but not least, our results present itself in the middle of the void that existed in the literature where both fMRI and EEG ISCs were related to popularity, but music was only evaluated by fMRI. That flagship study of Berns and Moore (2012) has been an example in neuromarketing for years, and our validation of the predictive approach using EEG provides great theoretical contributions. Additionally, the timing of the experiment within the first days after the album release is a unique aspect that is not shown in the previous research on film trailers. We therefore provided the results that bridge the gap in this line of research and provide a great theoretical contribution to the field of neuroforecasting, EEG-based neural similarity, and musical popularity prediction.

CONCLUSION

Thus, our results provide strong evidence for neural synchrony to be applicable as a predictor of population-wide digital streaming numbers and correspondingly the popularity of music with the large audience. Additionally, individual preferences

could be explained with Frontal Alpha Asymmetry or engagement. The practical impact lies with the music industry in the first place, enabling them to accurately assess the hit potential from their music samples and thereby distributing their resources more efficiently. Additionally, this metric might be applicable to neuromarketing research as forecasting consumer preferences lie at the heart of this discipline. By showing the predictive value of EEG-based neural synchrony on music, this research fills the void in the existing literature where previously popularity prediction had been done with movies, and music predicting had been done only with fMRI. The use of EEG and the application on music thus make this research unique within the existing literature.

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. Prior to the experiment, participants singed an informed consent in accordance with NMSBA Code of Ethics and EU GDPR guidelines.

AUTHOR CONTRIBUTIONS

TB, NF, and DP contributed to the conception and design of the study. NF and DP led the data collection process. NL performed the statistical analysis and wrote the first draft of the manuscript. All authors contributed to the manuscript revision, read, and approved the submitted version.

FUNDING

The experiment was made possible by the usage of Unravel Research's experimental equipment and participants database.

ACKNOWLEDGMENTS

Authors would like to thank Michiel Wiggers for his contribution to the data collection. Additionally, authors would like to express their gratitude to Tue Hvass, our iMotions Customer Success Manager for his support on the data collection and analysis.

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Conflict of Interest: TB, NF, and NL were employed by the company Unravel Research. Authors' employment do not depend on the outcomes or publication of this study. The authors declare no financial or otherwise competing conflicts of interest.

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frontiers in Psychology

ORIGINAL RESEARCH
published: 12 August 2021
doi: 10.3389/fpsyg.2021.673012

Job Assessment Through Bioelectrical Measures: A Neuromanagement Perspective

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During recruitment, human resource departments face two challenges: finding the right people for the job and attracting talent. Therefore, the hiring process requires both the ability to communicate a good company brand image and to understand the characteristics and potential of candidates. In this study, we used a neuroscientific approach to measure the experience of candidates during a job interview. The experiment involved 30 participants that individually took part in a job interview lasting 40 min. During the experiment, their engagement and stress levels were measured in real-time with skin conductance and electroencephalographic (EEG) data. From the results, we identified both the most stressful phases (the second and the fourth parts, relating to the explanation of the job and remuneration) and the most engaging phases (the first and the third phases, relating to the presentation of the company and the explanation of the career process) of the interview, suggesting implications for the assessment process. This study is a contribution to the field of neuromanagement, as a neuroscientific approach was applied to management issues in light of work and organizational psychology.

Keywords: neuromanagement, human resources, EEG, skin conductance, job assessment

OPEN ACCESS

Edited by:
Muddassar Sarfraz,
Nanjing University of Information Science and Technology, China

Reviewed by:
Marino Bonaiuto,
Sapienza University of Rome, Italy
Joanne Harris,
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *26 February 2021*
Accepted: *14 July 2021*
Published: *12 August 2021*

Citation:
Zito M, Bilucaglia M, Fici A, Gabrielli G and Russo V (2021) Job Assessment Through Bioelectrical Measures: A Neuromanagement Perspective. Front. Psychol. 12:673012. doi: 10.3389/fpsyg.2021.673012

INTRODUCTION

During the last decades, organizational needs and goals have changed and improved through the Tayloristic methodology, which focuses on new critical elements such as work motivation and the need of an individual to socialize in the workplace (Argentero, 2010). Indeed, the functioning of an organization depends on its working people, and investment in human resources has started to reflect this. As the awareness of what a candidate could contribute to an organization has grown, the assessment process has changed its focus, which has not only become technically oriented but also personality-oriented. These elements require the recruiter to have a new consideration of candidates who are no longer considered "passive" but participatory and able to express ideas, motivations, and goals during the job interview (Schneider et al., 2001), giving more elements to the recruiter who has to evaluate a candidate for a specific role or job, also in light of organizational growth (Abbasi et al., 2020).

Therefore, the selection process is seen as two-way, involving the interviewer and the candidate, with both parties taking an active role in the outcome (Argentero, 2010). If the latter can propose oneself as actively collecting information on the organization and on the job to evaluate the possibility of joining it, the selection process becomes an endeavor that not only seeks to understand

the characteristics and potential of the candidates, but also for the interviewer to communicate a good company image. While recruitment specialists have specific strategies for the evaluation of a candidate, the communication of brand image—that is to say, the attempt to "sell" the organization to attract the candidate—actually lacks. This means that the candidate may evaluate their expectations for the new job, also on the basis of previous jobs, by applying a sort of association with what is known that has to be balanced with what is desired. This has important implications for engagement and satisfaction (Davies et al., 2018). From the perspective of the company, this calls into consideration marketing rules and studies suggesting that the familiarity of a brand name has an advantage because of brand awareness, quality, and direct association (Ma et al., 2007). On the basis of these advantages, it is important for an organization that aims to attract talent to show both a good and coherent image of the company and a human resource structure oriented to a practical and positive organization (Schneider and Bowen, 1993; Zito et al., 2019), considering that brand names seem to be saved in the memory of people who are in a structure devoted to associative general knowledge (Keller, 1993). This is in line with the neuroeconomics assumption stating that professional expectations, activities, and relations leave a trace in the functioning of the brain (Cocco, 2016), conditioning subsequent behavior in similar situations.

On the evaluation side, however, emotional activation during a job interview needs to be considered; in fact, public speaking is suggested as a stressor (Sieverind et al., 2005). Moreover, contrary to the traditional assumption that considers job-seekers as rational in the search and choice processes (Kidd, 1998; Emmerling and Cherniss, 2003), other studies highlight the importance of examining the emotional side of these processes (Satpathy, 2012; Bonaccio et al., 2014). This is in line with the assumptions stating that the competitive nature of the selection process can develop negative affective states and stress (McCarthy and Goffin, 2004) and anxiety (Feiler and Powell, 2015; Powell et al., 2018), with the risk of compromising the evaluation of the candidate and his/her performance by the company during the assessment. In this sense, the individual characteristics of the candidate should also be detected, since studies highlight that some personality characteristics, such as conscientiousness, extraversion (Boudreau et al., 2001), and biographical elements, can determine success in a job interview and the ability to manage the evaluation situation (Tay et al., 2006). The issue of personal characteristics in the organizational environment leads also to important considerations on personal resources, positive aspects of the self, links to resilience, and the ability of individuals to control and manage their environment (Hobfoll et al., 2003). These resources can make people able to deal with demanding situations, have a protective role against stress, and allow individuals to perform better (Salanova et al., 2010; Xanthopoulou et al., 2013).

Encouraging the use and expression of such resources could be fundamental for the creation of a friendly and relaxed environment and useful to achieve organizational goals even during the assessment process. From this point of view, one of the resources considered important is self-efficacy. This resource can be useful in the mastery of challenging tasks and in the management of behavior during the job interview (Bandura and Schunk, 1981; Tay et al., 2006), with important consequences on work engagement (Barbier et al., 2012). Therefore, it would be worth considering that a job assessment situation that allows the candidates to experiment with self-efficacy through a relaxing situation—in particular, through a positive and peaceful job interview style—would also allow them to have a better performance. This would make the interview effective because it would allow the organization to detect the potential of the subject.

As for the evaluation of the reaction of the subject during the assessment situation, neurosciences could be a key element, as it provides a different interpretation between real experienced emotions and the rational side and gives the possibility to study the processing of information considering the role played by emotions (Passyn and Sujan, 2006). This approach finds applications among different fields, such as neuromarketing, neuroeconomy, and neuromanagement. The application of neuroscience to these different disciplines, in particular to consumer neuroscience, allows researchers to delve into and apply neuroscientific tools to detect the decision-making process (Plassmann et al., 2012, 2015; Bazzani et al., 2020). This discipline investigates the antecedents and consequences of behavior, looks at the biological side, and even focuses on the information processing and functioning of attention, memory, and emotion (Yarkoni et al., 2011; Plassmann et al., 2015).

Neuromanagement is a key concept by Prof. Qingguo Ma from the Zhejiang University that integrates economics and cognitive neuroscience with management sciences (Ma and Wang, 2006). The concept is based on a neuroscientific approach applied to management issues to explore behavioral and management processes and analyse brain activity. This allows researchers to understand the mental processes of people when facing management situations, human decision-making, and social behaviors and their influence on the management and economic processes (Parincu et al., 2020). Moreover, the neuroscientific approach allows for the reliable detection of emotions and mental processes also linked to self-regulation and social ability in several contexts, such as the professional one (Balconi and Salati, 2020).

According to studies on general consumer behaviors and decision processes, measurements based on the registration of neuro-physiological parameters could give accurate and reliable results because of the fact that they lack the mediation of cognitive processes (Poels and DeWitte, 2006; Missaglia et al., 2017). In fact, neuroscience, when applied to marketing issues, aims to discover what is happening in the brain in response to products or advertising stimuli and, in turn, discover which strategy can lead to the buying process (Ciceri et al., 2019; Russo et al., 2020).

Neuroscience techniques, which are focused on forms of interpretations of reality based on cognitive schemes and experienced emotions and on the detection of decision-making process, can be used and applied in any communication exchange activating a reaction that can be detected (Plassmann et al., 2015; Cocco, 2016; Bazzani et al., 2020). This approach can also help the specific assessment process by measuring reactions

useful for the choosing and meeting of organizational goals, detecting those elements related to engagement and stress, and supplying organizations with instruments to evaluate and conduct effective job interviews and, thus, meet their own organizational goals. In fact, being aware of the possibilities offered by recruiting strategies is crucial, since recruiting behavior can have implications in the design of labor market policies (Behrenz, 2001).

Taking together the aim of the research and the used techniques suggest that the meeting between the company needs of brand communication and recruitment evaluations is possible by joining the neurosciences science applied to management issues. In fact, neuromanagement in particular detects how communication can affect people within organizational and work situations (Venturella et al., 2017) through neuroscience instrumentation.

The main aim of this study is to measure the experience of the candidates during a job interview through a neuroscientific approach. The experiment provided a job interview with five different interviewers (A, B, C, D, and E), each belonging to one of the two main interview styles proposed in the literature (Raccanello, 2015; Argentero, 2016). These styles have been further exposed in the hypotheses section: one is characterized by many questions and is potentially stressful, and the other is a quiet style, also characterized by warmness and humor. Interviewers A and E belonged to the first category, while B, C, and D to belonged the second one. The interviews were structured job interviews and included four main phases:

- phase 1, the "ice breaker" and company presentation (namely, P1);
- phase 2, explanation of the work (namely, P2);
- phase 3, explanation of career possibilities (namely, P3);
- phase 4, agency mandate, with the specification of variable remuneration salary (namely, P4).

The four phases are expected to be linked to different engagement and stress levels, as mentioned in the hypotheses section.

To measure engagement and stress levels, we adopted two of the most widespread neuroscientific instruments in marketing research: the electroencephalogram (EEG) and skin conductance (SC) measurements (Alvino et al., 2020). The EEG measures the time-varying electric potential associated with the activity of a large number of neurons within the brain cortex. A differential activity between the left and right frontal cortices (the so-called frontal asymmetry) has been associated with emotional valence: the left frontal cortex is involved in experiencing positive emotions, while the right is involved in processing negative emotions (Davidson, 2004). Frontal asymmetry is defined in terms of frontal alpha asymmetry (FAA) since the electrical power in the alpha band (8–12 Hz) is inversely related to the neuronal activity: a greater left-over-right frontal asymmetry corresponds to a greater right-over-left frontal alpha prefrontal asymmetry and vice versa (Reznik and Allen, 2018). It has to be considered that emotions are defined as an adaptation to problems, and analyses on this topic should consider problematic situations as causes and/or consequences of emotions (Keltner and Gross, 1999). A positive valence underscores an approach toward the stimulus or an interest; on the other hand, a negative valence underscores avoidance toward the stimulus or a detachment (Harmon-Jones et al., 2010). The interest or detachment levels make it possible to understand the level of engagement toward the situations, as engagement is defined as a positive state of mind capturing the experience of a situation (Schaufeli and Bakker, 2010; Bakker and Albrecht, 2018). Moreover, a recent study also underscored the activation of prefrontal areas during the presentation of an advantage for the subject (Balconi and Fronda, 2020), an aspect considered linked to engagement. In this study, we operationalize the FAA as an indicator of engagement.

Skin conductance refers to the electrical conductance of the skin as a consequence of the sympathetic activity of the autonomic nervous system (ANS) on sudomotor nerves. Sudomotor nerves modulate the amount of sweat produced by the sweat glands, decreasing the electrical resistance of the sweat ducts and, in turn, increasing the net conductance of the skin. The skin conductance (SC) signal is modeled as the sum of two distinct components: the SC level (SCL), reflecting slow drifts, and the skin-conductance response (SCR), reflecting fast changes (Posada-Quintero and Chon, 2020). Scientific literature correlates SC and emotions, suggesting SC as a good indicator of arousal (Bolls et al., 2001; Ravaja, 2004; Gakhal and Senior, 2008; Sequeira et al., 2009) and stress or mental workload (Jacobs et al., 1994; Liapis et al., 2015; Greene et al., 2016). In particular, the phasic SCL has been previously adopted for measuring stress levels (Borghini et al., 2020). Accordingly, we operationalize the SCL as an indicator of stress.

EXPERIMENTAL HYPOTHESES

According to the main aim of the study, three hypotheses were developed following the neuromanagement perspective from both theoretical and empirical standpoints. Also considering the job perspective, the hypotheses were formulated in light of the literature regarding work and organizational psychology. It has to be noted that the first two hypotheses were particularly related to the phases of the interview, while the third one was related to the style of the interviewer.

This study operationalized the FAA as an indicator of engagement. From a job perspective, engagement is defined as a positive work-related state of mind that can capture how people experience a job situation (Schaufeli and Bakker, 2010; Bakker and Albrecht, 2018). In this view, a job becomes something that stimulates people by creating meaning and positive accomplishments. Linked to engagement assumptions, the assessment framework must also consider expectations (in terms of environment and advancements) of the future in a company, which is also a form of psychological contract (De Vos et al., 2009).

Hypothesis 1: The phases with higher levels of engagement are those related to the ice breaker and company presentation (P1) and career (P3).

If, on one hand, this study considered the most engaging phases, the research also assessed the most stressful parts of the interview with the operationalized SCL. Stress occurs in work situations and the main antecedents of job stress are related to the role in the organization, the career possibilities, the organizational and the distribution of the tasks structure (Cooper and Marshall, 1978), but also the job demands of an organization (Bakker and Demerouti, 2014), with consequences linked to exhaustion (Setti et al., 2018) and to the turnover intentions (Hallin and Danielson, 2008). This perspective has to be particularly considered in the variable remuneration rules explained in the fourth phase of this study since it could be linked to the perception of job insecurity, which can then make a job less appealing and become a source of perceived stress (De Witte, 1999; Witte et al., 2015). In order to avoid this scenario and in light of the anticipatory psychological contract, detecting this variable is important in the assessment step.

Hypothesis 2: The most stressful phases are those related to the explanation of the job (P2) and remuneration (P4).

Beyond observations on the engagement and stress indices, this study also explored the possible effect of the type of interview on the candidates. According to previous studies, the way of interaction between the interviewers and the candidates can be influenced by certain individual variables, in particular, quiet and positive moods that can strongly influence motivation and social behavior (Raccanello, 2015). A quiet style with transmitting positive moods can enhance flexibility, creativity, motivation, and cooperation (Isen and Reeve, 2005; Raccanello, 2015). This point is particularly crucial, considering that the performance of the candidates can be influenced by his/her perceptions of the situation during the job interview (Melchers et al., 2012). In particular, the affective approach during interviews, characterized by warmness, agreement, and humor, can contribute to the reduction of the anxiety of the candidates (Carless and Imber, 2007), whereas a competitive and pressing situation can lead the interviewed subject to anxiety and stress (McCarthy and Goffin, 2004). Furthermore, an effective approach can be characterized by the personalization level of communication style (Scheuer, 2001); that is, the inclusion of elements linked to the self or expressing personal feelings or experiences, thus establishing a relationship between the interviewer and the candidate. Accordingly, this would put the candidates who feel warmness, more commitment, and encouragement in the personal interaction at ease (Scheuer, 2001; Raccanello, 2015).

Among other theoretical standpoints, the way of conducting an interview can be based on different styles (Argentero, 2016). The first can be defined as "friendly," in which the power of the exchange is equally distributed. This style is not always the best choice in job assessment, since the interviewer needs to conduct the interview. Another style is based on a professional exchange based on assertiveness. In this case, questions and answers alternate, and both interlocutors are involved in a positive atmosphere of mutual openness, with the aim of creating a relaxed situation based on respect and trust. Finally, another style can be based on the so-called "stress interview." In this case, the interview involves a series of questions (a sort of "interrogation") posed in a direct and even intrusive way, for which precise answers are expected, in a strongly structured situation where interaction is exclusively guided by the interviewer. This results in a tense and uncomfortable atmosphere, which was created to understand how the candidate can react in stressful situations but not allowing the candidate to express his/her potential and, moreover, not allowing the organization to understand the real competencies and skills of the candidate.

On the basis of the above-mentioned theoretical standpoints, we assume that a cooperative and positive atmosphere would be more productive and favorable for both the organization and the candidate. On one hand, studies highlight the need for environments that can put their candidates at ease (Argentero, 2010), also in light of the possibility for these candidates to feel positive emotions and perform well (Demerouti, 2006; Zito et al., 2019). On the other hand, studies also focus on the crucial role of the support received by the candidate during the job interview as a resource that can decrease the level of stress (Frisch et al., 2014, 2015). Assuming these theoretical points of view, we operationalized the conduction styles as shown in the following method section. It is, therefore, hypothesized that:

Hypothesis 3: A calm and peaceful style of interview (B, C, and D) will produce less stress in the candidate.

MATERIALS AND METHODS

Sample and Procedures

This study has been conducted in the specific framework of assessments: a large Swiss company involved in the energy market made available its standardized interview, which is used to assess candidates looking for a job in the company. This company is very solid in the European labor market; therefore, this study considered the assessment interview as a consistent basis to test a novel neuroscientific approach for human resources.

The participants were real candidates who applied for a real job interview. They were informed about the experiment, and they voluntarily accepted to perform their assessment within the laboratory conditions. There were 30 participants (13 males; 17 females) with an age range of between 25 and 45 years ($M = 35.23$, $SD = 8.05$) and were both high school and university graduates looking for a job. All the participants signed an informed consent before the experimental procedure began. None of the participants reported any history of brain disorders or neurological surgery at the date of the enrolment.

In order to avoid a possible carry-over effect, the participants were randomly assigned to the different interviewers that the company assigned to the assessment. Six candidates were assigned to each interviewer. The interviewers were chosen by the energy company, and they belonged to that organization. The researchers could not intervene in the choice of interviewers.

After entering the laboratory, the researchers explained to the participants all the procedures and the phases they were going to experience. In order to track real-time engagement and stress levels, the participants wore two lightweight and wearable devices for EEG and SC measurement. The setting reflected an

assessment situation with the interviewer and candidate sitting and facing each other.

A 60-s long baseline phase (P0) was recorded before the beginning of the interview. The subjects were not given any particular instructions, except for trying to relax as much as possible while both the EEG and SC basal activities were recorded according to previous studies (Bilucaglia et al., 2019; Gabrielli et al., 2020; Laureanti et al., 2020; Russo et al., 2021).

As for the style of the interviewers, according to the above-mentioned theoretical standpoints on the type of interviews and on the basis of conducting style of the interviewers participating in the research, we operationalized two main categories of styles. We provided an observation that considered the method of interviewing and then a classification of the style on the basis of the observed characteristics (Mason, 1994; Jamshed, 2014). This classification followed the characteristics shown in the literature in terms of styles and consequences on the candidates. Going more in-depth, we identified two main styles: the first is characterized by a positive atmosphere with a quiet and peaceful style aimed at putting the candidate at ease through warmness, humor, and openness (Isen and Reeve, 2005; Raccanello, 2015). This type of style was associated with interviewers B, C, and D. The second style is characterized by a lot of questions in a short time and in a competitive and stressful atmosphere (McCarthy and Goffin, 2004; Argentero, 2016). This type of style was associated with interviewers A and E.

Instrumentation

The electroencephalogram data were recorded using B-Alert X10 (ABM Inc. New York, NY, United States), which is a wearable and wireless headset. It has nine Ag/AgCl wet electrodes (arranged in a monopolar montage) embedded in a flexible plastic strip, located at the F3, Fz, F4, C3, Cz, C4, P3, POz, and P4 sites of the 10/20 system (Jasper, 1958). The device allows the linked mastoid reference based on two Ag/AgCl adhesive patches placed on M1 and M2. The sample frequency is 256 Hz, and the resolution is 12 bits (Hairston et al., 2014). Prior to the application of the Synapse© conductive cream (Kustomer Kinetics Inc., Arcadia, CA, United States), the skin was properly scrubbed with 70% isopropyl alcohol in order to reduce electrode impedance. The SC signal was recorded using the Shimmer 3 GSR+ (Shimmer Sensing Ltd., Boston, MA, United States), which is a wearable and wireless bracket-like device. According to the recommendations in the literature (Boucsein et al., 2012), SC was recorded using a constant-voltage mode (0.5 V) by means of two Ag/AgCl electrodes placed on the index and ring fingers of the non-dominant hand.

Both the electroencephalogram and SC wireless data streams were collected with a personal computer (PC) and synchronized using iMotions v.6.1 (iMotions, A/S, Copenhagen, Denmark), an integrated software research platform. The interviews were recorded using a LifeCam Studio webcam (Microsoft Corporation, Redmond, WA, United States), and the video was real-time synchronized to both the electroencephalogram (EEG) and SC data by iMotions. The video recordings served to segment each interview into the above-mentioned phases (P1, P2, P3, and P4).

Data Processing

The EEG data were processed using iMotions and B-Alert software development kits (SDKs). First, the decontamination procedure illustrated by Berka et al. (2007) was applied. Noise (e.g., spikes, high voltage excursions) and artifact (e.g., eye blinks, EMG noise) data points were identified by means of either a wavelet transform or thresholds on both the amplitude and the time, as well as using a linear discriminant analysis classifier. Depending on their type (i.e., noise or artifacts), the identified points were either filtered by means of the wavelet transform or simply set to zero.

Then, the decontaminated EEG signal was segmented using a 1-s long Keiser window with 50% overlapping. By means of the B-Alert SDKs, for each frontal channel k, the power spectral density (PSD) was computed within each window and averaged every three windows, obtaining a time signal of concatenated PSDs and $PSD_k(t)$ with a temporal resolution of 1 s. The alpha powers of F3 and F4 channels, $p_{F3}(t)$ and $p_{F4}(t)$, were automatically computed by integrating the corresponding $PSD_{F3}(t)$ and $PSD_{F4}(t)$ in the alpha band (8–12 Hz). A logarithmic transformation was performed in order to mitigate the skewness of the power values. The frontal alpha asymmetry FAA(t) (Reznik and Allen, 2018) was computed as:

$$FAA(t) = \log\{p_{F3}(t)\} - \log\{p_{F4}(t)\}$$

The obtained FAA(t) was then exported to Matlab R2016 (Mathworks Inc., Natick, MA, United States) and segmented according to the phases of the interview identified by means of video recordings. Within each segment, the outliers were detected using the inter-quantile range (IQR) criteria, as those data points outside the interval [Q1–1.5 × IQR; Q3 + 1.5 × IQR], where Q1 and Q3 are, respectively, the first and third quartiles (Russo et al., 2021). Outlier points, set as "Not-A-Number," were excluded from subsequent analyses. In order to remove subjective variability (Bilucaglia et al., 2019; Gabrielli et al., 2020), FAA(t) was z-score transformed as:

$$FAA(t) = (FAA_0(t) - m)/s$$

where $FAA_0(t)$ is the untransformed FAA signal, and m and s are the temporal mean and the temporal standard deviation of $FAA_0(t)$, respectively, calculated in the baseline phase (P0). Because of the standard deviation in the denominator, the z-score transformation makes any dimensional signals (e.g., the power values expressed in μV^2 or conductance value expressed as μS) unitless. Finally, z-scored segments were temporally averaged in order to get a condensed phase-related indicator FAA_i. This procedure was applied on each subject i, giving a set of averaged indicators indexed as $FAA_{i,j}$.

The SC data were exported to Matlab and filtered using a second order low-pass FIR filter ($f_c = 1$ Hz), as a simple procedure to attenuate external noise and large artifacts (Posada-Quintero and Chon, 2020). Then, a low-pass FIR filter (fc = 1×10^{-12} Hz, 8,192 samples long) was applied in order to extract the tonic SCL component (Subramanian et al., 2019). Similar to those of the EEG, the SCL data were finally segmented into

TABLE 1 | Mean (M) and standard deviation (SD) for the FAA and SCL z-scores, split into the four phases of the interview.

		P1	P2	P3	P4
FAA	M	0.502	0.448	0.504	0.363
	SD	0.053	0.044	0.033	0.051
SCL	M	19.999	35.012	25.940	42.838
	SD	8.925	8.261	13.098	8.613

the interview phases i, cleaned from the outliers using the IQR criterion, z-score transformed, and temporally averaged to obtain a condensed phase-related indicator SCL_i. The procedure was applied on each subject j, giving a set of averaged indicators, indexed as $SCL_{i,j}$.

Statistical Analyses

Statistical analyses were performed using JASP v.0.14 (Love et al., 2019). FAA and SCL indicators were analyzed by two-way mixed ANOVA, considering the interviewer as a between-subject factor (five levels: A, B, C, D, and E) and a within-subject factor the interview phase (four levels: P1, P2, P3, and P4). Prior to the analyses, the sphericity of the phase factor and the equality of variances for the interviewer factor were assessed by the Levene's and Mauchly's tests, respectively (Verma, 2015).

RESULTS

The results allowed us to identify the most stressful and most engaging phases of the interview, as well as understand which interview strategies can reduce the stress level and improve the engagement of candidates. **Table 1** shows the mean scores (M) and the standard deviations (SD) of the indicators (z-score transformed FAA and SCL), split for the four phases of the interview.

The results regarding the different phases are shown within the following hypothesis sub-paragraphs. Among the results, it is interesting to monitor data along the different interview styles through the general trend. For this reason, many results in the Figures are split within the interviewers.

Hypothesis 1

For the FAA, both the interviewer main effect and the interviewer × phase interaction were not significant [$F_{(4,25)} = 1.892$, $p = 0.143$, $\eta^2 = 0.018$ and $F_{(12,75)} = 0.0394$, $p = 0.962$, $\eta^2 = 0.617$, respectively], while the phase main effect was significant [$F_{(3,75)} = 55.254$; $p < 0.001$]. *Post-hoc t*-tests with Bonferroni's correction confirmed a significant difference between all the phases (all $p < 0.001$), except between P1 and P3 ($p > 0.05$). The highest FAA values were found in the phases P3 (M = 0.504, SD = 0.033) and P1 (M = 0.502, SD = 0.053) and associated with career possibilities and ice-break company presentation, respectively. The lowest FAA values were found in P4 (M = 0.363, SD = 0.051) and associated with agency mandate, followed by P2 (M = 0.484, SD = 0.044), which was associated with work explanation.

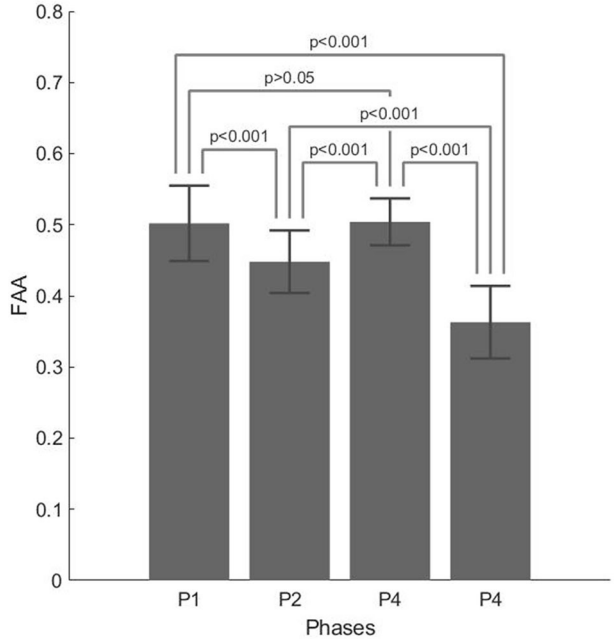

FIGURE 1 | Descriptive plot with error bars for frontal alpha asymmetry (FAA) z-scores split for the four phases of the interview.

TABLE 2 | Mean (M) and standard deviation (SD) of the FAA z-scores, split into the four phases of the interview.

	P1	P2	P3	P4
M	0.502	0.484	0.504	0.363
SD	0.053	0.044	0.033	0.051

Figure 1 and **Table 2** report the following, respectively: descriptive plot (with error bars) and descriptive statistics of the EEG data split in the four phases of the interview.

Hypothesis 2

For skin conductance level, the interview × phase interaction effect was not significant [$F_{(12,75)} = 0.778$, $p = 0.671$, $\eta^2 = 0.034$], while the phase showed a significant main effect [$F_{(3,75)} = 40.685$; $p < 0.001$, $\eta^2 = 0.443$]. *Post-hoc t*-tests with Bonferroni's correction confirmed a significant difference between all the phases (all $p < 0.001$, except for P1–P2 and P2–P4 where $p < 0.01$). The highest skin conductance level (SCL) values were found in P4 (M = 42.838, SD = 8.613) and P2 (M = 35.012, SD = 8.261), which were associated with agency mandate and work explanation, respectively. The lowest SCL values were found in P1 (M = 19.999, SD = 8.925), the phase associated with ice-break company presentation, followed by P3 (M = 25.941, SD = 13.098), the phase associated with career possibilities.

Figure 2 and **Table 3** report the following, respectively: descriptive plot (with error bars) and descriptive statistics of the SC data, split in the four phases of the interview.

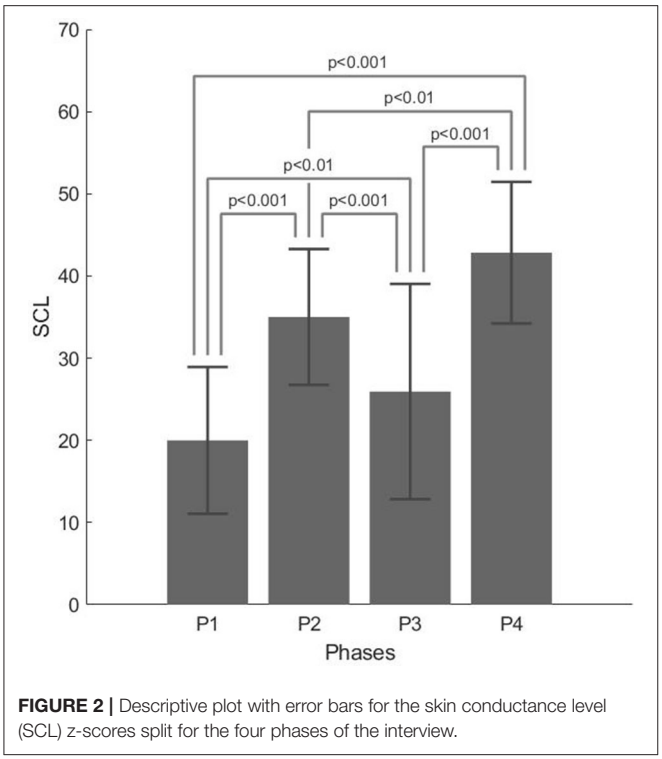

FIGURE 2 | Descriptive plot with error bars for the skin conductance level (SCL) z-scores split for the four phases of the interview.

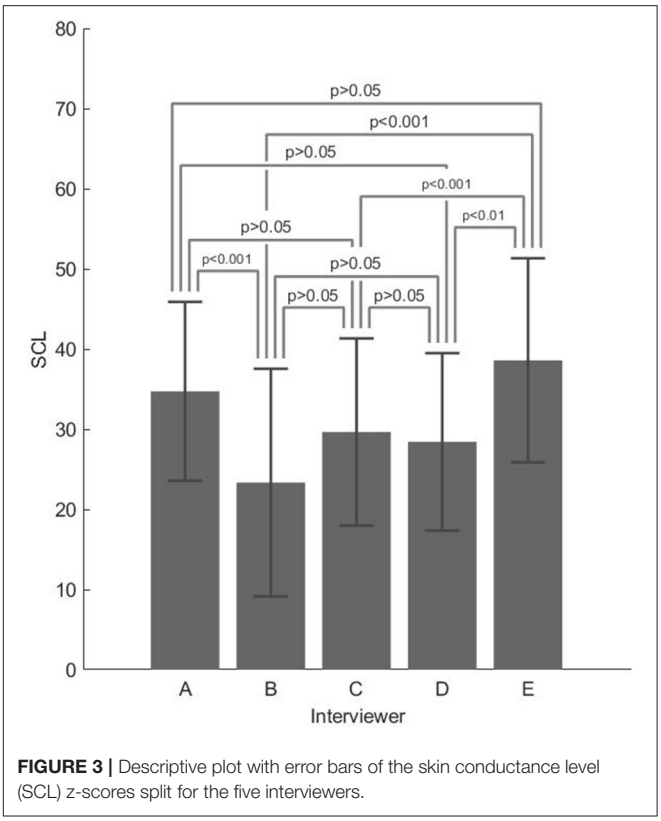

FIGURE 3 | Descriptive plot with error bars of the skin conductance level (SCL) z-scores split for the five interviewers.

TABLE 3 | Mean (M) and standard deviation (SD) of the SCL z-scores, split into the four phases of the interview.

	P1	P2	P3	P4
M	19.999	35.012	25.941	42.838
SD	8.925	8.261	13.098	8.613

TABLE 4 | Mean (M) and standard deviation (SD) of the SCL z-scores, split into the five interviewers.

	A	B	C	D	E
M	34.727	23.345	29.652	28.422	38.590
SD	11.155	14.195	11.673	11.071	12.729

Hypothesis 3

For the skin conductance level (SCL), the main effect of the interviewer was significant [$F_{(4,25)} = 11.462$; $p < 0.001$, $\eta^2 = 0.162$]. *Post-hoc t*-tests with Bonferroni's correction confirmed a significant difference between A–B ($p < 0.001$), B–E ($p < 0.001$), C–E ($p < 0.001$), and D–E ($p < 0.01$). The highest SCL values were found for A (M = 34.727, SD = 11.155) and E (M = 38.59, SD = 12.729), where the interviewers characterized by a warm and humoristic style. The lowest SCL values were found for B (M = 23.345, SD = 14.195), C (M = 29.652, SD = 11.673), and D (M = 28.422, SD = 11.071), the interviewers characterized by many questions and potentially stressful.

Figure 3 and **Table 4** report the following, respectively: descriptive plot (with error bars) and descriptive statistics of the SCL z-scores, split among the five interviewers.

Despite both the interviewer main effect and the interviewer × phase interaction being not significant, the highest frontal alpha asymmetry (FAA) value was found for A (M = 0.469, SD = 0.072), while the lowest one was found for E (M = 0.422, SD = 0.087) where both the interviewers were characterized by a warm and humoristic style.

Figure 4 and **Table 5** report the following, respectively: descriptive plot (with error bars) and descriptive statistics of the FAA z-scores, split among the five interviewers.

DISCUSSION

In this study, we recorded the EEG and SC data of 30 candidates during a 40-min long structured job interview in order to monitor in real-time their engagement and stress levels. The engagement was operationalized through the FAA, and the stress through tonic SCL. The subjects were randomly assigned to five interviewers who differed in interview style: two interviewers were characterized by a style with many stressful questions (A, E) and three interviewers by a more focused, warm, and humorous approach (B, C, and D). The interviews were divided into four phases, characterized by different engagement and stress levels: the "ice breaker" (P1), explanation of the work (P2), career possibilities (P3), and agency mandate (P4). We hypothesized that the different phases would produce different engagement and stress levels (Hypotheses 1 and 2), and that the different

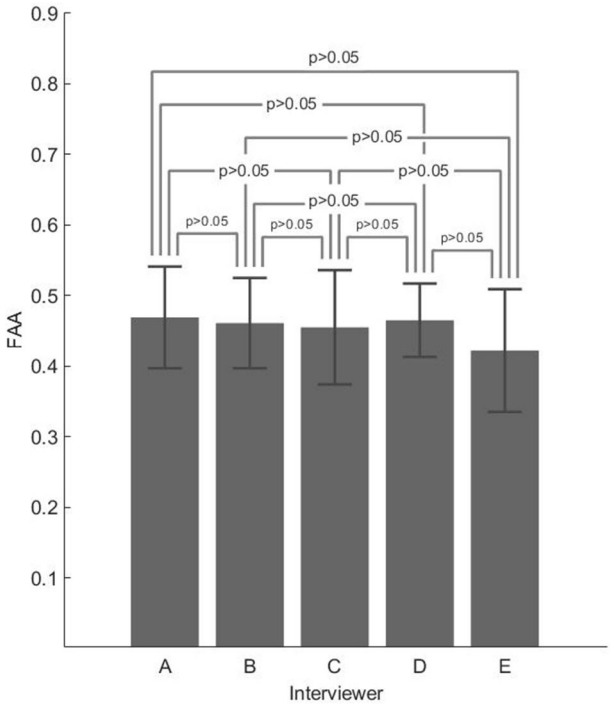

FIGURE 4 | Descriptive plot with error bars of the frontal alpha asymmetry (FAA) z-scores split for the five interviewers.

TABLE 5 | Mean (M) and SD of the FAA z-scores, split into the five interviewers.

	A	B	C	D	E
M	0.469	0.461	0.455	0.465	0.422
SD	0.072	0.064	0.081	0.052	0.087

interviewers would produce, on average, different stress levels (Hypothesis 3).

Among the results, the FAA showed that the most engaging phases were P1, referred to as the ice-breaking activity and presentation of the company, and P3, related to the explanation of career possibility, confirming hypothesis 1. The FAA was operationalized as an indicator of engagement that the literature suggests to be linked to positive work-related states of mind that capture how people can experience a job (Schaufeli and Bakker, 2010; Bakker and Albrecht, 2018). According to studies, job engagement reflects the creation of meaning associated with the job and, from the perspective of the candidates, these aspects, referred to as the expectations on the environment and on what a future in the company could be, appear relevant from a development standpoint. This point, indeed, is defined as crucial in assessment dynamics, since expectations are seen as an anticipatory psychological contract; that is, the belief of individuals in the employment also concerns guarantees to the future employer and expected inducements (De Vos et al., 2009), and is functional to psychological empowerment and employee engagement in future organizational actions (Sandhya and Sulphey, 2019).

On the side of skin conductance level (SCL), data showed that P1, the phase related to the ice-breaking activity and company presentation, is characterized by less stress. Read together with the higher level of FAA measurement, it could lie on the possibility for building a new perspective, collecting information about the company, and evaluating what the guarantee of the candidates could be. These results are also linked to the possibility of experimenting with the so-called "good stress" (Karasek et al., 1998), which implicates the development of active behaviors when demanding situations that are in line with the possibility to decide, therefore leading to motivation or new learning behaviors. In contrast to this first more relaxed phase, SCL underscores that P2, related to the explanation of the job, and P4, referred to as agency mandate with the specific characteristics of the VAT number and explanation of work with variable remuneration, are the most stressful for the candidates. These results, confirming hypothesis 2, could be related, on one hand, to the effort to understand the organization of the job and distributions of the role applied for (Cooper and Marshall, 1978; Setti et al., 2018). On the other hand, the results on P4 could be related to the fact that variable remuneration provides a high effort or unknown reward outcomes. Indeed, remuneration, beyond career satisfaction, is considered a crucial work value in determining career success, which often makes candidates expect high financial rewards (Dries et al., 2008). Variable remuneration is also linked to the issue of duration of the work contract and, therefore, job insecurity, which is a crucial and discussed topic in the field of work and organizational psychology. The psychological concept of job insecurity refers to concerns about the fear of losing a job and becoming unemployed (Rothschild and Hyun, 1990; Sverke and Hellgren, 2002). Job insecurity, indeed, is conceptualized as a source of stress (De Witte, 1999; Witte et al., 2015), with detrimental effects on the well-being of employees and their psychological and physical health (Sverke and Hellgren, 2002; Emberland and Rundmo, 2010; Laszlo et al., 2010; Kerse et al., 2018). Therefore, when evaluating a job situation, this point has to be considered in the enhancement (even reduction) of stress levels.

As for the styles of the interviewers, even if this is the first step of the research, the style based on many questions to the candidates (A and E) produced more stress; on the other hand, the quiet and peaceful style (B, C, and D) seemed to produce less stress in the candidates, confirming hypothesis 3. The non-significant results for the FAA suggest that the style of interview does not affect the engagement of the candidate. The results are in line with the two main styles that we operationalized. At this point in the research, this could be linked to the influence of effect on job interviews (Raccanello, 2015). In fact, a competitive selection can foster the rising of negative affective states, such as stress, frustration, and anxiety (McCarthy and Goffin, 2004), even compromising the performance of the candidates but also reducing their ability to adopt successful strategies (Bonaccio et al., 2014). On the other hand, the affective approach of the interviewers, characterized by warmness, agreement, and humor, can have a role in reducing the anxiety of candidates (Carless and

Imber, 2007). Moreover, as already highlighted, it is important to consider the role of support (also in terms of a supporting atmosphere), even coming from the interviewers, since it could be functional in decreasing the levels of stress among candidates (Frisch et al., 2014, 2015). On the basis of the conduction style, it is suggested to deepen expectations and the aspirations from the beginning, referring to the experiences, passions, and hobbies of the candidates. Moreover, it is suggested to encourage the candidates to share these aspirations, leaving space for their stories, to understand the attitudes and qualities of the person, and to put the candidate at ease in order to enhance their self-efficacy (Consiglio et al., 2016). Starting from the result of this study, it is important to present company qualities, especially from an economic-financial point of view with a long history behind it. Underlining its uniqueness and linking it to a complete offer of products and services could be strategic to sell the company image and communicate a good company brand image (Ma et al., 2007); it may also be useful for positive evaluation from the candidates. Moreover, focusing both on the expectations of the candidates and on the presentation of the company is useful to prevent the presence of people looking for a job without any awareness or with haphazard job search strategies (Bonaccio et al., 2014).

As for stress produced by those several questions that are necessary to know the characteristics, attitudes, and expectations of the candidates, it could be useful to offer resources, such as support from supervisors or the possibility to have job autonomy, in line with the Job Demands-Resources Model (Bakker and Demerouti, 2014). Considering not only the demands but also the resources that an organization could make available for employees could reduce distress outcomes and foster well-being. This can also be done through positive experience at work, which is functional to protect from emotional or cognitive and physical exhaustion (Zito et al., 2016). In fact, a situation of strain can also occur when the psychological demands are higher than the possibility to use a very important resource, such as autonomy (Zito et al., 2019) or decision latitude (Karasek and Theorell, 1990).

As the psychological contract plays a relevant role (De Vos et al., 2009), it could also be useful to create an adequate interview on the expectations to meet the needs of the company and the candidate, in order to better reach organizational goals.

Neuromanagement is quite a young discipline, and this study would contribute to deepening this issue in light of organizational psychology. In line with recent guidelines and studies on neuromanagement, it has to be underscored that this discipline can design new intervention strategies that can develop a direct evaluation of both individual potential and performance (Parincu, 2019; Balconi and Salati, 2020) with a positive outcome on employee growth and organizational efficacy. As neuromanagement deepens the research on this subject, it is important to consider that this is the first discipline to look at an organizational issue considering the brain processes deriving from the dynamics in an organization and allowing the detection of human brain actions and interactions in the business context from the neuroscience perspective (Ghadiri et al., 2012). In this sense, neuromanagement can be useful for the emotional brain and building of social connections, helping organizations in managing emotions in the workplace (Parincu, 2019), and preventing negative emotional dynamics and designing positive emotional and collaborative workplaces. This would be particularly useful in the perspective of assessment, in which it is important to detect the real aspect and potential of candidates. In light of the potential of the individual, the possibility to use neuroscience tools during the assessment session could be functional in better capturing the abilities and qualities of an individual. This would match important organizational aims such as informing employees of their future perspectives and possibilities or advising employees on the job to improve career opportunities (Balconi and Salati, 2020). This is an interesting point to deepen and to take into account that this study has also confirmed with the high engagement of candidates found in P3, which is related to the explanation of career possibilities. In this sense, even if this is a first pilot study, it uses a neuroscientific approach that can be a first contribution to understanding their abilities and potential. Understanding the engaging and stressful elements in this crucial phase is very important to select the right person and to understand the phases to be activated for their growth, even in terms of organizational performance. Moreover, having participatory and engaged candidates is functional for organizations to communicate the characteristics and all the crucial information needed to "sell" the job to the ideal candidate.

Even if this is a first exploratory study, as listed, it calls into consideration different implications and practical suggestions for human resources departments engaged in the assessment process. Knowing the psychological and physiological implications of the different phases of the hiring dynamics not only allows companies to attract and identify the right employees but also to plan future organizational implications. In fact, involved and motivated individuals aware of the challenges and possible available resources can contribute to the creation of positive organizational environments (Zito et al., 2016). This is functional to enhance motivation and give meaning to the job with positive consequences on performance and on individual and collective well-being (Demerouti, 2006; Cantele, 2018), also in light of the importance of investing in human resources management policies related to human capital and the evaluation and enhancement of the resources of the individuals (Manuti et al., 2020) that are identified as competitive advantages for an organization.

The limitation of this study is related to the detection of a unique work context. This did not permit the generalization of results, but it gives suggestions for the management of job interviews in pursuit of reaching organizational goals. Even with this limitation, however, this study shows an important strength, since it uses neuroscience techniques that allowing the capture of real reactions in real-time, which is useful in declining new assessment and evaluation directions. In fact, at the implication level, the ability of the interviewers to adapt to the candidate and to create empathy was crucial, though an in-depth analysis of personal aspects and life experiences was not strictly linked to a mere work aspect. Therefore, applying the neuroscience approach to strategic company planning that considers both the

internal organization and the external communication appeared to be a key factor, and it allowed it to flow into the issue of neuromanagement. This approach can also be useful to explore organizational processes and the way to react and cope with daily job circumstances (Venturella et al., 2017). Moreover, the fact of collecting data in real-time allows us to have data on real reactions, not mediated by cognitive elaborations typical of the retrospective approach. Another limitation of the study is the classification of the characteristics of the interviews only on the basis of observations. Future studies should classify these characteristics (such as humorous or stressful cadencies) also considering the characteristics, traits, and expertise of the interviewers. A limitation of this study is also linked to large standard deviations, particularly for the SCL data. This could be linked to the different characteristics of the candidates composing the sample (Van Voorhis and Morgan, 2007), and future studies should also consider and detect these aspects.

For the future, this study should collect more data among different working categories in order to try to generalize data, and to extend and detect critical phases among other working contexts and cultures. Moreover, age should be useful in the investigation of the stress reactions that could be particularly highlighted within young job-seekers, since they would be less able to manage emotions because of their inexperience in job assessment (Bonaccio et al., 2014).

Furthermore, interesting points for the future could be the detection of possible differences between women and men and the analysis if the level of salivary cortisol before, during, and after job interviews, which would help researchers understand and correlate hormone fluctuations among different steps and interview phases with stress and activation reactions. This could be in line with studies indicating different gender approaches to risky decision-making, which seem to be influenced by different levels of stress hormones (van de Bos et al., 2014). Finally, future studies should replicate this study by also taking into account the reactions of the interviewers, investigating, e.g., the bioelectrical signal similarities with the candidate (Gabrielli et al., 2020). According to the emotional contagion assumptions (Hatfield et al., 1993), people tend to mimic facial or vocal expression, postures, and behaviors of people around them; thus, also acquiring their emotions. This could be functional in detecting how the interviewer can influence the candidate, and suggests the need for specific training to conduct assessments that are functional to put the subject at ease. This is also in line with theory about the "chameleon effect" (Tanner et al., 2008), which suggests that people tend to unconsciously imitate the body movements and facial expressions of others, also in order to facilitate the emotional connection. This effect could also be used to condition the behavior of others: it could be interesting that the awareness of a trained interviewer can be used to positively affect the mood of a candidate in order to reduce stress levels and increase his/her performance, allowing the company to conduct a more precise selection process.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics committee of Università IULM. Participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VR and GG designed the research. MB and AF collected the data and carried out data analysis and interpretation. MZ and MB wrote the manuscript. MZ, AF, and VR edited the final version. VR and GG supervised the project and the writing of the study. All the authors contributed to this study, final version of the manuscript has been approved for submission, and accountable for the whole study.

ACKNOWLEDGMENTS

We would like to thank Megan Wright for editing and reviewing this manuscript in the English language.

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frontiers in Psychology

ORIGINAL RESEARCH
published: 12 October 2021
doi: 10.3389/fpsyg.2021.674159

Applying Implicit Association Test Techniques and Facial Expression Analyses in the Comparative Evaluation of Website User Experience

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OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: 28 February 2021
Accepted: 07 September 2021
Published: 12 October 2021

Citation:
Mauri M, Rancati G, Gaggioli A and Riva G (2021) Applying Implicit Association Test Techniques and Facial Expression Analyses in the Comparative Evaluation of Website User Experience. Front. Psychol. 12:674159. doi: 10.3389/fpsyg.2021.674159

This research project has the goal to verify whether the application of neuromarketing techniques, such as implicit association test (IAT) techniques and emotional facial expressions analyses may contribute to the assessment of user experience (UX) during and after website navigation. These techniques have been widely and positively applied in assessing customer experience (CX); however, little is known about their simultaneous application in the field of UX. As a specific context, the experience raised by different websites from two well-known automotive brands was compared. About 160 Italian university students were enrolled in an online experimental study. Participants performed a Brand Association Reaction Time Test (BARTT) version of the IAT where the two brands were compared according to different semantic dimensions already used in the automotive field. After completing the BARTT test, the participants navigated the target website: 80 participants navigated the first brand website, while the other half navigated the second brand website (between-subject design). During the first 3 min of website navigation, emotional facial expressions were recorded. The participants were asked to freely navigate the website home page, look for a car model and its characteristics and price, use the customising tool, and in the end, look for assistance. After the website navigation, all the participants performed, a second time, the BARTT version of the IAT, where the two brands were compared again, this time to assess whether the website navigation may impact the Implicit Associations previously detected. A traditional evaluation of the two websites was carried on by means of the classic heuristic evaluation. Findings from this study show, first of all, the significant results provided by neuromarketing techniques in the field of UX, as IAT can provide a positive application for assessing UX played by brand websites, thanks to the comparison of eventual changes in time reaction between the test performed before and after website navigation exposure. Secondly, results from emotional facial expression analyses during the navigation of both brand websites showed significant differences between the two

brands, allowing the researchers to predict the emotional impact raised by each website. Finally, the positive correlation with heuristic evaluation shows that neuromarketing can be successfully applied in UX.

Keywords: facial expression, emotions, user experience (UX), brand association, online experiment

INTRODUCTION

Advances in technology, digital transformation, cost pressure, and the emergence of new channels have considerably changed the way customers shop and interact with brands (Gauri et al., 2016; Lemon and Verhoef, 2016; Bolton et al., 2018; Grewal et al., 2018; Lee, 2020). Furthermore, the challenges faced during the COVID-19 pandemic have brought companies to rethink their business models (Boudet et al., 2020). Today, customers are following a cross-channel customer journey rather than a linear path to purchase (Harris et al., 2020), and this big shift in consumer behaviour transforms them from buyers to users, moving the focus on the customer, and user experience (UX) (Sheth, 2021). Therefore, classic research techniques primarily based on qualitative methods such as self-report measures and interviews, largely predominating in UX research (Pettersson et al., 2018), require development for new UX evaluation methods. This development can improve practicability and scientific quality (Vermeeren et al., 2010), leading to multidisciplinary research methods based on more objective data (Verhulst et al., 2019). Among them, neuromarketing represents an evolving field of scientific investigations that have shown valuable understanding of consumer behaviour and its links with emotions in perception and decision-making processes. This area combines theories and practises from fields of behavioural sciences, including neuroscience, psychology, and sociology, to determine the reasoning and patterns of choices of consumers. As defined by Ale Smidts, as the first definition of the term, neuromarketing is, "*the study of the cerebral mechanism to understand the consumer's behaviour in order to improve the marketing strategies*" (Stasi et al., 2018).

In the field of neuromarketing, the most significant techniques are based on eye tracking, electroencephalography (EEG), fMRI, psychophysiology, analysis of facial expressions, and reaction times (Gacioppo and Petty, 1985; Stasi et al., 2018). Although neuromarketing techniques have been largely applied to customer experience (CX) (Gacioppo and Petty, 1985; Klinčeková, 2016), none of these techniques are commonly applied to UX, except for eye-tracking and a few pioneering studies relying on neuro and psychophysiological measurements (Bender and Sung, 2021). Emotions are considered a key point in UX, as mentioned by Marc Hassenzahl, one of the most quoted researchers in UX and its hedonic impact: "Reformers of Human Computer Interaction (HCI), often stress that the old HCI is, in essence, cognitive (i.e., focused on memory, task, etc.), and that the future lies in emotions" (Hassenzahl, 2004). Jakob Nielsen, one of the most well-known researchers in UX, in 1990, provided a set of nine "usability principles," enabling the identification of all main problems when using HCI interfaces, software, and websites. However, in this set of usability principles, none of them was addressing attention to the emotional impact played by all these kinds of experiences. This lack was filled in a few years later, when Nielsen updated his list of nine "usability principles," adding a 10th one, labelled as "aesthetic design" (Nielsen, 1994b), thus recognising the importance of the emotional impact played by the digital experience. Nevertheless, the way to investigate this additional principle is still mainly based on the opinion of expert evaluators as deeper described later in this article, mentioning the heuristic evaluation procedure. Almost two decades ago, Don Norman, another of the most quoted researchers in the field of UX, highlighted, and explained the importance of "emotional design" in products and services (Norman, 2004). Although famous scientists highlighted the importance of this factor, there is a lack of scientific procedures to characterise and measure this specific domain in UX. For this reason, as already stated, there is the need of developing new methods allowing to assess, according to empirical procedures, the effects of emotional impact played by UX. The present research brings light to this specific topic, showing how the application of two neuromarketing techniques allows researchers to assess and rank different websites in terms of emotional responses. One technique is based on an implicit association test (IAT) in relation to emotional items presented before and after website navigation to verify whether navigation can change short-term associations, as no previous research tried to apply this method to evaluate website experiences. The other technique is related to affective responses in terms of facial expression analyses during navigation, as little is shown by scientific literature in the field of UX and website design. The simultaneous application of both techniques, together with a traditional one relying on heuristic evaluation, allows researchers to explore whether the use of neuromarketing methods can improve the scientific measurement of the emotional design of websites, widening the application of neuromarketing techniques from CX to UX.

RELATED RESEARCH WORK

The IAT helps researchers identify biases through reaction times and emotions and has been developed into a marketing-oriented variation known as the Brand Association Reaction Time Test (BARTT) to expand on the understanding of consumer behaviour. This technique can clarify how consumers value the brand by distinguishing biases among participants through their intentional efforts to conceal attitudes towards concepts. When using IAT for evaluating brand associations, the data collected can indicate the subject biases and determine hierarchies of products by analysing reaction time as well as latencies in the way participants associate concepts (Bercea,

2012; Gregg and Klymowsky, 2013). Greenwald showed the reliability of this technique in his early IAT experiments, regarding pleasant/unpleasant associations, showing that the delays of participants, or lack thereof, indicate bias in addition to the choices selected (Greenwald et al., 1998). In this regard, the importance of this method can be argued for marketing research as a means of determining the biases of the customers through their conscious choices to avoid displaying biases. These biases are shown distinctly through the response latencies in the association of the concepts. Beginning with the seminal work of Keller (1993) and Aaker (2009), the brand association became an important topic, supported by the demand of marketers to have clear guidelines of brands in their business and managerial decisions. However, the literature shows a lack of research, enabling to highlight how brand associations may be modified by communication activities, in particular to websites communication strategies. Some research experiments already presented significant results about methods to measure brand image based on the constellation of associations (Till et al., 2011; Schnittka et al., 2012; Camarrone and Van Hulle, 2019). Some other research projects showed how brand associations can be efficiently applied to advertising assessments (Janakiraman et al., 2009; Anderson and Simester, 2013; Caldato et al., 2020). However, no previous research tried to investigate how brand associations vary depending on stimuli represented by a website. Brand associations are frequently characterised by a static mental map; however, what happens when users are exposed to a website? Does the mental map vary accordingly? Furthermore, to generate strong brands, firms have to implement a set of positive associations around them (Till et al., 2011; Flight and Coker, 2016). Through marketing actions, firms can identify, strengthen, or alter the associations linked to their brands (Keller, 1993), changing their competitive placement. The experience of a brand and consequently, its associations can be directly shaped by firms or can be even transferred by other brands or factors (Keller, 2003). Quite well-known examples are brand endorsement, co-branding, and brand extensions of celebrities (Martini et al., 2016). In this vision, the experience of a brand may be transferred to another one, if there are some bonds linking them. These bonds can also be retrieved in the brands of competitors as some associations are shared among different brands operating in the same market business. Based on the "transfer property," what happens when competitors attempt to strengthen brand associations shared by the company? All these questions are still awaiting a proper and empirical answer. One of the aims of this research project is to fulfil the lack of scientific literature in the field of website communication and UX, exploring the dynamics of brand associations after being exposed to a website experience. In this way, it is possible to verify whether such exposure may raise short-term variations in the power of brand associations, not only on a specific brand but also on a competing one that may share some similar associations. Last but not least, as the impact of webpages on brand perception can be classified as an application of reaction time techniques in testing marketing stimuli, some positive evidence addressing the feasibility of such an application about the digital experience is supported by few pioneering studies (Matukin et al., 2016; Matukin and Ohme, 2017). Many methods from neuroscience research have been adopted to be used in marketing research (Clement et al., 2013; Missaglia et al., 2017; Songa et al., 2019), such as the IAT, but little is known about the possibilities these methods have in the area of UX with the exeption of few pioneering studies that show how to derive emotions from user mouse behaviour (Yi et al., 2020). User experience encompasses how people experience things around them, including products, websites, and services (Bojko, 2013). The Nielsen Norman Group defines UX as providing what the customer needs without hassle, crafting products that are a joy to own or use, and the "*seamless merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design"* (Nielsen and Norman, 2021). Inherently, UX is multifaceted and touches on various parts of the use of a service, system, or product (Quaglini, 2020). To aid in the understanding of UX, researchers have relied greatly on a neuromarketing technique, such as eye tracking. It is especially relevant in evaluating the UX of websites and interfaces because it grants researchers the visual perspective of a user and allows to establish the findability of specific calls to action (Mele and Federici, 2012; Fu et al., 2017). Two primary reasons researchers use eye tracking are that it is non-invasive and can help determine how a consumer reacts during his or her interactions with a web product or service. Eye movements from the user can be fixations and saccades, and the movements of the eyes can indicate emotions such as confusion when the eyes return to a previous point (Bergstrom and Schall, 2014, p. 55–57). This tool is significant to researchers pursuing information about how consumers experience websites because the eyes of a person are drawn to and remain in places that result in further thinking, and the action of looking at a subject directly requires little conscious effort as it is a more reflexive process (Bojko, 2013). Points the eyes of users are drawn to on a web page contribute to fixation patterns that eye tracking technology can record, and these data can be converted into gaze plots and heat maps to determine points of significant focus on a web page (Djamasbi, 2014). Understanding the user behaviour on websites informs us about the decisions he or she makes, including ones to navigate away from the web page due to clutter or disorganisation. If a website suffers from these and other problems, it may result in an exhaustive review, which often frustrates the user since it is a product of a website that is not user-friendly (Nielsen and Pernice, 2010, p. 376). By using eye tracking, researchers can determine how a user views a site and navigates good or bad website design to improve the design for better UX. Therefore, eye tracking is a common and useful tool for researchers of UX. However, eye tracking does not help researchers understand a user's comprehension of a subject nor does it help indicate how a participant emotionally engages with the material in question (Bojko, 2013). Even though eye tracking is a useful tool for neuromarketing research and UX research, it, alone, does not provide the entirety of data needed to create an effective website. The IAT helps to understand the comprehension and opinions of a user towards a brand/subject/service or product, such as a website. Understanding brand association in consumers is integral to determining brand equity. Brand associations, as explained by Keller (1993), can be partitioned into three

categories: associations of positive or negative favorability, uniqueness, and strength of associations (Gattol et al., 2011). In addition to these three elements, there is the relevance of the association and how this connexion may or may not present as a motivating factor, and the number of associations the consumer has (Gattol et al., 2011). A consumer may have significant associations for a brand, influencing the likelihood of a purchase from that brand as well as potential brand loyalty. A study analysing brand association in relation to a focus of prediction showed that participants had a significant association of brand names with cake flavour and quality (Van Osselaer and Janiszewski, 2001). Analysis of brand associations clarifies brand equity, and the aforementioned study establishes brand associations can lead to the positive favorability of a brand. However, previous studies of brand association have not utilised the technique of the IAT to evaluate the website experience of a user. The present project applied, for the first time, the BARTT to assess the effects of the experiences of two websites and to verify whether this technique can provide significant results enabling to measure and compare the effects of different website designs in relation to both emotional and cognitive items. The appliance of this neuromarketing technique to UX and website design widens the range of neuromarketing from customer to UX, verifying whether digital experiences can change short-term associations.

Additionally, the understanding of facial expressions helps researchers comprehend the emotional engagement and experience of a user towards the stimuli he/she has been exposed to during the navigation of a website. Automatic facial expressions analyses, efficiently used in neuromarketing to evaluate optimal advertising spots (Lewinski et al., 2014b; Lewinski, 2015; Hamelin et al., 2017; Cherubino et al., 2019) or the level of engagement during social media interactions (Schreiner et al., 2019), could lead to additional insights into UX research to improve the effects in terms of emotional design (Small and Verrochi, 2009; Norman, 2013; Hamelin et al., 2017; Danner and Duerrschmid, 2018). Facial expressions are part of non-verbal communication, which has been highlighted for a long time in the scientific literature as enabling to bring important information aside from verbal expressions (Stewart et al., 1987; Puccinelli et al., 2010). In this study, the affective reactions to websites will be measured in a quantitative way by means of autonomic responses, namely facial expressions. This allows the researchers to overcome some of the limitations of the most used tools in UX research, where the evaluation of emotional impact is mainly based on qualitative methods such as interviews. The feasibility of this approach is widened when an automated tool is utilised, engaging commercially available, advanced, and unobtrusive software that catches and analyses facial expressions of emotions. This solution has been already used in many different contexts related to experimental research in consumer behaviour. There are already several scientific studies showing how the use of automated facial analysis of expressions provides positive results in assessing CX (de Wijk et al., 2012; He et al., 2012; Terzis et al., 2013; Danner et al., 2014; El Haj et al., 2017; Noordewier and van Dijk, 2019; Riem and Karreman, 2019; Meng et al., 2020). Recently, new pioneering studies presented by the scientific literature have shown the possibility to take advantage of face orientation aside from facial expression to predict the hedonic impact of the face presentation of models, as the facial orientation to the right-side significantly predicts with a more negative evaluation, while on the opposite, face orientation towards left side significantly correlates with a positive evaluation of the models' face presentation (Park et al., 2021). Facial expressions reveal affective states defined, for instance, in EMFACS-7 (Friesen and Ekman, 1978) and thus possibly predict related behaviour and attitude modification (Kulczynski et al., 2016). Facial expressions of emotions are universal sequences of facial muscle contractions associated with the emotional state of the person. The neuro-cultural theory of emotion, developed by Paul Ekman (e.g., Ekman, 1972; Ekman and Cordaro, 2011), defines facial expressions of emotion as discrete, innate, and culturally independent. According to other studies, there is a two-way connexion between facial expressions and emotion regulation (Cole, 1986; Izard, 1990; Gross and Thompson, 2007; Gross, 2014). Therefore, in studying facial expressions, it is difficult to establish causal relationships between facial non-verbal behaviour and interpretations assigned to them—emotions. Emotions do cause facial expressions ("I feel happy, so I smile"), but facial expressions also cause emotions ("I smile and it makes me happy"). Any causal relationship between smiling and perception of the website has not been established in the UX context. Smiling or laughing may indicate liking for the website and, therefore, greater effectiveness of the website. Analysing facial expressions and user reactions to website interfaces identifies potential frustrations that can be improved for future users (Branco, 2006). Methods of facial expressions evaluation based on automatic software analyses further the understanding of the interaction of a user with one interface over another (Andersen et al., 2014), as well as the overall experience of the user with digital tools and resources (Liu and Lee, 2018). To understand UX based on emotions and facial expressions, the participants completed a series of tasks while sitting in front of a traditional PC equipped with a camera, allowing the software to measure the emotional reactions they had while interacting with a website, as this approach has been previously explored with positive results from pioneering studies (Hazlett, 2003). The technique of facial expression analysis has been used little by researchers of UX (Branco, 2006; Munim et al., 2017) despite its value in clarifying the frustration and joy of users during their interactions. According to Hancock et al., "Hedonomics," (Hancock et al., 2005) defined as "the promotion of pleasurable human-machine interaction" by its creators, it is possible to highlight the key role of the so-called "emotional design" (Norman, 2004) as a fundamental factor in UX. The present research aims to explore whether the automatic facial expressions analyses may provide useful information related to the emotional reaction raised by website experiences. This research can expand the use of automatic facial expressions, helping professionals in measuring the effects of website emotional design according to more empirical procedures.

In conjunction with the two above techniques described, we integrated traditional heuristic evaluation (Nielsen and Molich, 1990; Nielsen, 1992) performed by five experts from the UX field. Combining traditional heuristic evaluation with innovative

techniques based on reaction time and facial expression analyses can allow to explore whether the results from classic qualitative method based on heuristic evaluation converge or contrast with findings emerging from the use of quantitative methods based on facial expression analyses and reaction time measures. In the case of convergence, it may be possible to envisage a further integration of these innovative quantitative methods in UX research. On the opposite, in the case of divergence or contrast, it may be possible to understand whether these two different approaches are measuring different phenomena of UX. Jakob Nielsen developed the heuristic evaluation method together with usability consultant Rolf Molich in 1990 due to their many years of experience in teaching and consulting about usability and UX. As defined by the two authors, "there are four main methods to evaluate a user interface: formally, by some analysis techniques; automatically, by a computerised procedure; empirically, by experiments with test users; and heuristically, by simply looking at the interface and passing judgment according to one's own opinion" (Nielsen and Molich, 1990). In particular, the authors reported that "most user interface evaluations are heuristic evaluations, but almost nothing is known about this kind of evaluation since it has been seen as inferior by most researchers." For this reason, they presented four experiments, enabling to derive a small set of nine "basic usability principles," performed by at least three different professionals, enabling to identify all main problems. Few years later, Nielsen refined the heuristics based on a factor analysis of 249 usability problems (Nielsen, 1994a) that allowed the definition of a set of heuristics with maximum explanatory power, resulting in this revised set of heuristics that are used today by most professionals and organisations for user interface design (Nielsen, 1994b): visibility of system status; a match between system and the real world; user control and freedom; consistency and standards; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; help users recognise, diagnose, and recover from errors; help and documentation. Before this work, the guidelines were so many that a professional could need a lot of time before accomplishing it. For instance, Smith and Mosier's guidelines for designing user interface software have 944 items and remain one of the largest collections of publicly available user interface guidelines (Smith and Mosier, 1986). Another set of research-based heuristics has been proposed by Gerhardt-Powals (1996) to provide an alternative to Nielsen and Molich's list. Theoretically, all heuristics proposed to share the same purpose to established usability standards that, if enhanced, can provide a better UX about products or services. Unfortunately, "usability problems" are often identified by means of qualitative methods, relying on the opinion of expert evaluators (Catani and Biers, 1998). On one side, part of the problem could be explained considering that usability professionals have their own favourite sets of heuristics; on the other side, the problem is that there is not a research-based set of heuristics shared by the scientific community and based on international consensus. Moreover, the scientific literature addressed the need to update the heuristics provided many years ago: "with the rapid expansion and growth of technology in the last 20 years, Nielsen's 10 usability heuristics may need an update to remain consistent with modern usability problems" (Gonzalez-Holland et al., 2017). The present research study used a version of a heuristic evaluation set with 247 heuristics related to usability problems identified by Nielsen and revised specifically for website experience in the modern context, used in the professional field (Travis, 2017). The heuristic evaluation has been provided by five different professionals to establish whether a traditional and most-used method in UX may support findings from facial expressions analyses and reaction times techniques.

The inclusion of classic methods like heuristic evaluation with innovative techniques from the Neuromarketing field based on facial expression analysis and IAT helps to understand whether or not the combination of these different approaches may widen the insights on how UX is affected by the emotional design shaping websites contents and interactions.

Finally, both the BARTT/IAT and facial expression analysis have unique benefits in the current COVID-19 pandemic as they are reliable methods of obtaining information that can be collected and recorded without in-person interactions, taking complete advantage of a remote setting. The participants used a personal computer equipped with its camera to provide their facial recordings during the tasks assigned, releasing the needed data, enabling them to perform an automatic facial expression analysis. The IAT also only requires the use of a personal computer to be accomplished. Both parts of the experiment can be administered by the researcher through a video call or even an audio call, eliminating any need to meet all the participants in person. Due to the global pandemic, the need for health and safety of all those involved in the study was a high priority, so we relied on technology and internet connexion to acquire both accurate and safe data.

Regarding the subject of our experiment, we chose automotive sites from two American brands due to the impact of the pandemic on this industry. This research is intended to investigate how the brands might take advantage of innovative insights for developing new digital strategies to overcome the crises raised by the COVID-19 pandemic and improve automotive sales through their websites.

MATERIALS AND METHODS

The study was conducted between October 2020 and December 2020, and a sample consisting of 160 students (80 men, 80 women; mean age, 23 $\pm$ 4) was recruited from the Catholic University of Milan. One criterion was established to qualify the sample: The participants had to be in-market for a car and intended to purchase it within an appropriate time frame of 2–3 months. In the event that the website proposed cars beyond their budget, we asked them to identify themselves with a potential buyer. The participants who had already made their minds about exactly which car they were going to buy were removed from the sample to exclude the possibility that the participants might have already exhausted their capacity for exploration and evaluation of the website. The fact that all the participants are university students provides the limit that

all results are representative of this specific population, and further research with broader samples in terms of age range and low/high skills in information technology may establish whether the results here presented can be representative of the whole general population. All the participants were required to have an internet connexion and a personal computer equipped with a webcam. The minimum definition resolution required to participate in the test is a standard high-definition of 1,280 × 720 pixels (HD Ready or 720 pixels). Two websites from the automotive field have been selected to perform a comparative test: Ford and Tesla (version exposed in 2020). This study was performed remotely by utilising software, including iCode, for online IAT provided by NEUROHM and FaceReader 8.1 software from Noldus for emotional facial expression analysis. All of the participants completed an online, pre-test survey that related to the application of IAT.

iCode, an online platform in the field of reaction time recording, was used to assess the speed in providing their answers from all the participants in this project. iCode accurately reflects the attitudes of the participants by using a two-part calibration process to analyse response time (iCode., 2019). Part one of the calibration process of iCode uses motoric tasks to establish the movement speed and familiarity with the device of each participant (iCode., 2019). The calibration of iCode consists of pressing the answer buttons without any cognitive load. It also serves as a tutorial for respondents as it makes them familiar with using the scale. Part two of the calibration process of iCode tests how fast the participants read statements of different lengths. Each participant was given a statement and one answer button to press when he/she finished reading the statement. The influence of statement length on corresponding response times is minimised, allowing statements of different lengths to be compared (iCode., 2019). iCode uses Neurohm's Confidence Index to ensure accuracy and helps researchers determine the emotional certainty of participant opinions. However, to perform a statistical analysis according to indications shared in the scientific literature, results from this project rely on raw data expressed in milliseconds recorded by the iCode online platform.

Facial expressions of the participants were recorded during web page navigation and processed in post-test using FaceReader, version 8.1, from Noldus (Noldus, 2014; Loijens and Krips, 2019). Objective facial measurements were used to capture reactions to website exposure (Den Uyl and Van Kuilenburg, 2005). This system uses a three-layer neural network that automatically identifies and examines facial expressions of emotions in human beings (Den Uyl and Van Kuilenburg, 2005). It detects and classifies facial expressions both from pictures and videos into one of the following basic emotions: happy, sad, angry, surprised, scared, disgusted, contempt, and neutral (Ekman, 1972). Facial expressions, like happiness, sadness, etc., are examined in FaceReader on a frame-by-frame method. This is since basic emotions can usually be expressed in full within a single frame (snapshot) of the face. However, there exist many more complex affects, which are not completely expressed with a single instance but rather, over a longer amount of time. These longer temporal facial affects are called "*affective attitudes*." With the release of FaceReader 7.1, the analysis of three commonly occurring affective attitudes, namely: interest, boredom, and confusion has been introduced. Unlike regular facial expressions, these affective attitudes are computed over a time window (typically from 2 to 5 s), rather than a frame-by-frame method. Therefore, the intensity of the affective attitude at any point in time of analysis does not just depend upon the current analysis of the face but also on the last 2 pr 5-s history of facial analysis. In addition, some of these affective attitudes also take into account certain additional facial cues like nodding or head shaking, which are also internally computed over the analysis history. The literature on the affective attitudes is still exploring the accuracy of these additional metrics (Borges et al., 2019; Hirt et al., 2019); we provide here results related to confusion, as particularly useful to evaluate the impact of website experience here considered, as previous research showed positive results in considering subtle expressions (Salgado-Montejo et al., 2015).

First, FaceReader detects a face using the so-called "Active Template Method." Second, the software builds a virtual, superimposed 3D "Active Appearance Model" of the face, featuring nearly 500 distinctive landmarks. The third step measures the intensity and probability of facial expressions, enabling basic emotions to be computed (Van Kuilenburg et al., 2005). The neural network of the system has been trained, taking advantage of a high-quality correlation of approximately 10,000 images that were manually annotated by real human expert coders. The average scores of performances reported are 89% (Den Uyl and Van Kuilenburg, 2005; Van Kuilenburg et al., 2005) and 87% (Terzis et al., 2013). We consider in this study in the present project results only about "happiness," as the accuracy of this specific emotion is the highest in comparison to all other emotions according to the scientific literature (Lewinski et al., 2014a,b; Stöckli et al., 2018; Dupré et al., 2020). Although FaceReader can analyse offline videos, our study required the participants to have a live webcam to classify facial expressions in real time. FaceReader contains five different face models that are used to find the best fit for the face that is going to be analysed. The models include: (1) "General," the default face model; (2) "Children," the face model for children between ages 3 and 10 years old; (3) "East Asian," the face model for people of East Asian descent (Zhi et al., 2017) e.g., Korean, Japanese, and/or Chinese; (4) "Elderly," a model for participants 60 years of age and older; (5) "Baby FaceReader," different software for infants between ages 6 and 24 months old. We set FaceReader to "General" for this study to account for the mean age (23) and nationality (Italian) of the participants.

We did not use FaceReader's Participation or Group calibration. Instead, we used "in the wild," or spontaneous, facial expression data to predict real-world consumer responses. Facial expressions, often caused by a mixture of emotions, can occur simultaneously at high intensities (Loijens and Krips, 2019). Spontaneous facial expressions are, therefore, processed immediately after being recorded. This process works well for larger samples; thus, spontaneous facial expressions were ideal for our study of 160 participants. Spontaneous expressions can also provide a benchmark for comparisons between different algorithms (Küster et al., 2020). We relied on a minimum of 90% of accurate facial analysis through all FaceReader analyses

detected for each participant: each participant has been exposed to the website for a total of 3 min, and his/her facial expressions have been recorded for a total of 180 s. Only recordings that FaceReader processed properly for at least 162 s were considered. However, results from the 16 participants (seven from the group assigned to the Tesla website and nine from the group assigned to the Ford website) were discarded due to the participants leaning into the camera, covering their faces, or otherwise interfering with the tracking and expression analysis of the FaceReader. We enrolled 16 additional participants, according to gender characteristics and willingness to purchase a car within the next trimester. In this way, the researchers have been able to make up for those discarded and checked in real time the quality of facial expression analysis to collect datasets of 80 participants for each group.

All the participants were guided by a researcher to complete the protocol steps of the study. Prior to completing the study, consent forms were sent to the participants *via* email. The implicit association pre-test was sent to the participants through an email link. The following statements were used in the pre-test: reliable (affidabile), passion (passione), I would like to own it (mi piacerebbe averla), comfortable (confortevole), innovative (innovativa), I would like to have it (mi piacerebbe averla), electric (elettrica), safe (sicura), traditional (tradizionale), affordable (accessibile). All statements were presented in association with the logo of the two brands: eighty participants undertook a "response latency" task, in which they were asked to respond "yes" or "no" to each brand/association pair. According to the model of Till et al. (2011), we consider the speed of response as an implicit measure of the association strength: the faster the response to the association, the stronger the association. We also recorded the number of explicit responses in terms of "yes" or "no," as well as the speed of their responses, which are defined as "response latency." Our procedure was based on the "Brand Association Reaction Time Task" (BARTT) script provided by iCode, which enables measurement of the frequencies and reaction times of opinions of the participants as to whether or not words are associated with the target brands, as described in Till et al. (2011). Based on the theoretical perspective described in the method section, our procedure was designed to find out the associations that are part of the immediate network of a brand and to provide an analysis of those associations in terms of their frequency and strength; regarding the "frequency," it is defined as "the number of mentions over the associations to the brand": as shown by Teichert and Schöntag (2010), the more respondents have similar associations, the higher the average node strength. Relating to the "strength," it is defined as follows: "the latency of response to the brand associations" (Sanbonmatsu and Fazio, 1990). The faster the subjects responded to the target investigation, the stronger the association. For each brand (TESLA and FORD), we first calculated the "Frequency of Associations" (FoA) and, secondly, the "Strength of Associations" (SoA). Only the "yes" answers were considered both for FoA and SoA (Till et al., 2011).

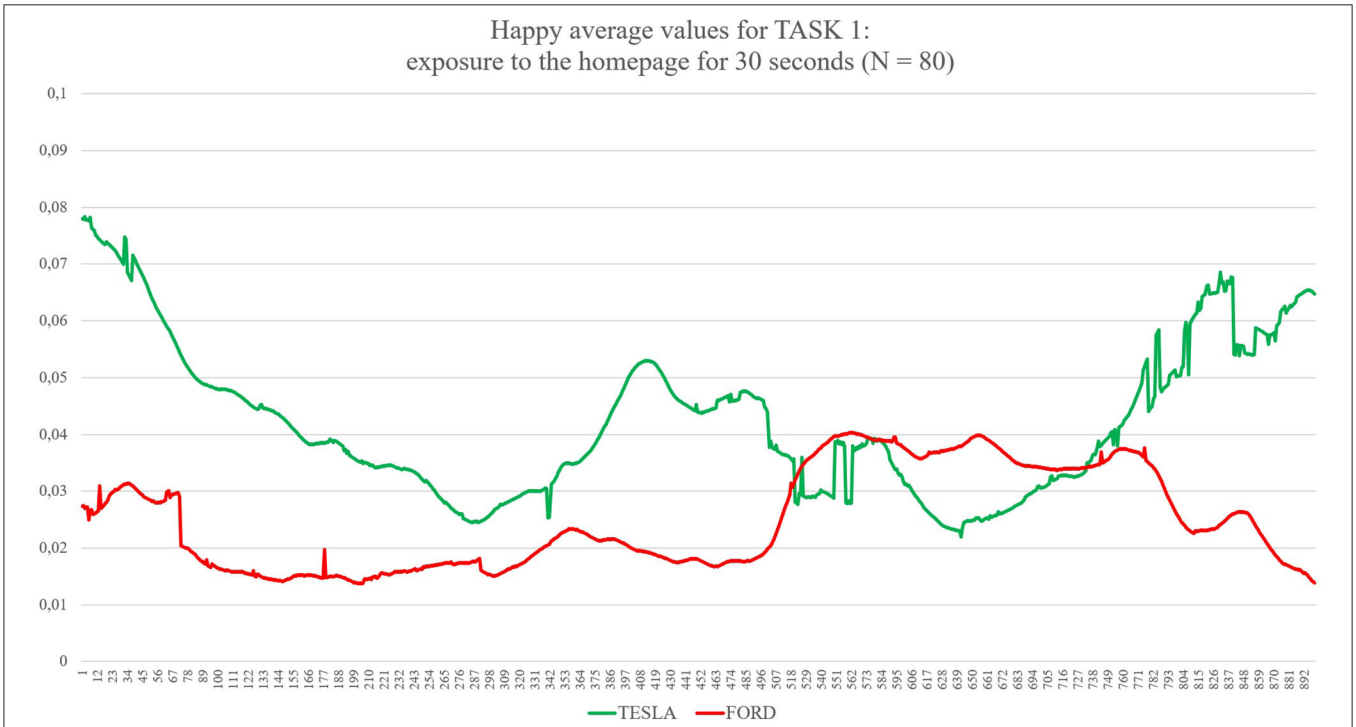

FIGURE 1 | The graph shows continuous values of Happiness for both Ford and Tesla during Task 1 (exploration of the homepage for 30 s). The average levels of happiness are higher during the exploration of the Tesla website compared with Ford. On the X axis, time is expressed in 30 samples per second for a total of 900 samples, corresponding to 30 s as the total amount of time exposure. On the Y axis, values of happiness are expressed between 0 (no happiness expressed by the face) and 1 (highest intensity of happiness expressed by the face).

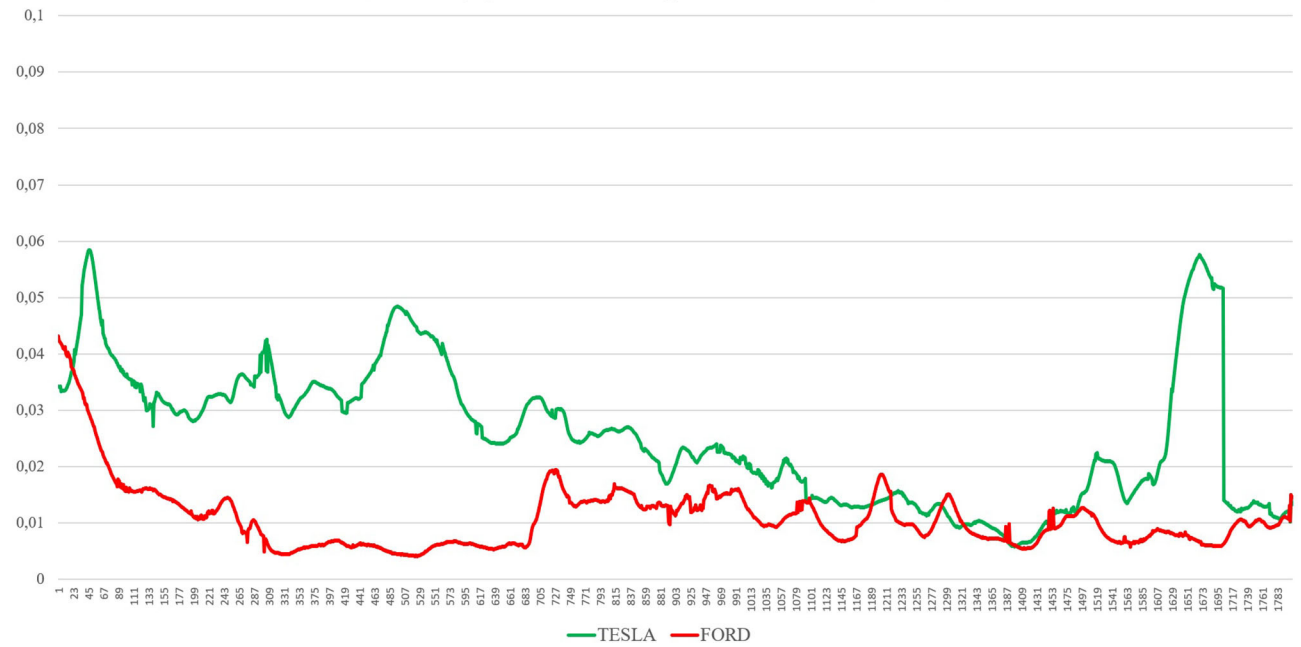

FIGURE 2 | The graph shows values for Happiness for both Tesla and Ford during Task 2 (subjects were asked to look for characteristics of a specific car model). On the X axis, time is expressed in 30 samples per second for a total of 1,800 samples, corresponding to 60 s as the total maximum amount of time exposure to the website during this task. On the Y axes, values of happiness are expressed between 0 (no happiness expressed by the face) and 1 (highest intensity of happiness expressed by the face).

The 160 participants were randomly assigned to either Ford or Tesla. About 80 participants navigated Ford's website, and the other 80 participants navigated Tesla's website.

The web page navigation process required the participants to complete four navigation steps. If a participant was unable to complete a task within the allotted time, the task was marked as failed. However, the participants were not penalised for failure and could proceed to the next step. The participants would signal to the researcher that they are ready to begin the task by showing a thumbs-up or waving. The participants would then use a webcam to record themselves completing the task. After the participants completed the four navigation tasks, all video recordings would be sent to the researcher for analysis.

Task 1, the first impression test, exposed each group to its randomly assigned website homepage for 30 s. The participants were asked to only scroll and avoid clicking when interacting with the homepage of the website (as shown in **Figure 1**). Task 2 gave participants 1 min to look for a specific model and its functional characteristics, such as acceleration, maximum speed, efficiency, and price (as shown in **Figure 2**). The participants randomly assigned to Tesla were asked to find the "Model X," and the participants randomly assigned to Ford were asked to find the "New Explorer.[1]" The "Model X" and "New Explorer" are comparable in price. Task 3 gave the participants 1 min to customise a specified vehicle model. The participants randomly assigned to Tesla designed a "Model 3," while the participants randomly assigned to Ford customised a "Mustang Bullitt[2]" (as shown in **Figure 3**). Task 4 asked both groups to envisage the need for assistance to find information on electric battery packs (as shown in **Figure 4**). For the task to be successful, the participants were required to utilise the search bar. Thus, the participants who found the information without the search bar failed the task. All the participants from both groups were given 30 s to complete Task 4.

After completing the four tasks, both groups were instructed to complete the implicit association post-test. All 160 participants completed the same implicit association post-test, regardless of their assigned company. During the post-test, the participants were asked to apply their perception of the two homepages after UX. The participants were asked if they associate the homepage of Tesla and/or Ford with the following perception characteristics: Trust and Credibility, Easy Navigation, Pleasant Visual Design, Promotion, Clear Information, and Assistance. All these items were chosen from the dimensions used in heuristic evaluation in order to compare results from both techniques, with the exception of "Promotion," which was selected as there is a strong difference between the FORD website, rich of promotions, and TESLA website, where there are no promotions. Screenshots of

[1]The "New Explorer" sold on the Ford Italy site is equivalent to the "2021 Explorer" sold on the U.S. site.

[2] The Ford "Mustang Bullitt" is no longer in production as of January 31, 2021 (Foote, 2021).

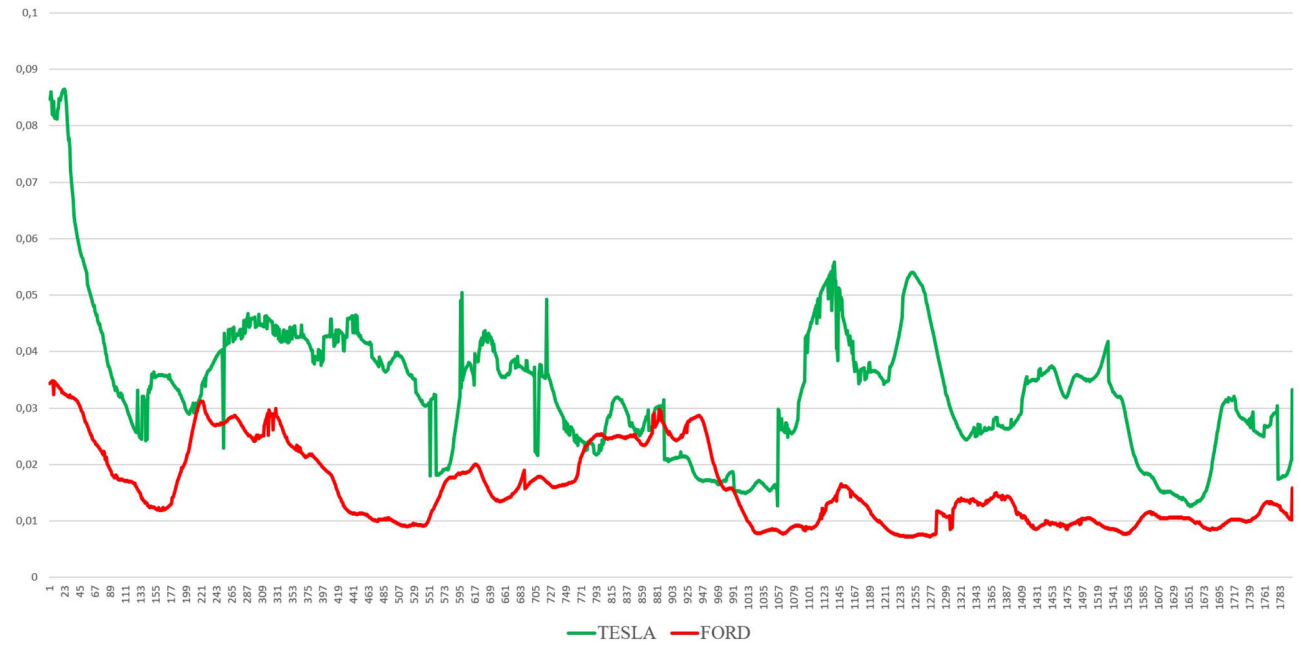

FIGURE 3 | The graph shows values for Happiness both for Tesla and Ford during Task 3 (subjects were asked to use the customising tool). On the X axis, time is expressed in 30 samples per second for a total of 1,800 samples, corresponding to 60 s as the total maximum amount of time exposure to the websites for this task. On the Y axes values of happiness are expressed between 0 (no happiness expressed by the face) and 1 (highest intensity of happiness expressed by the face).

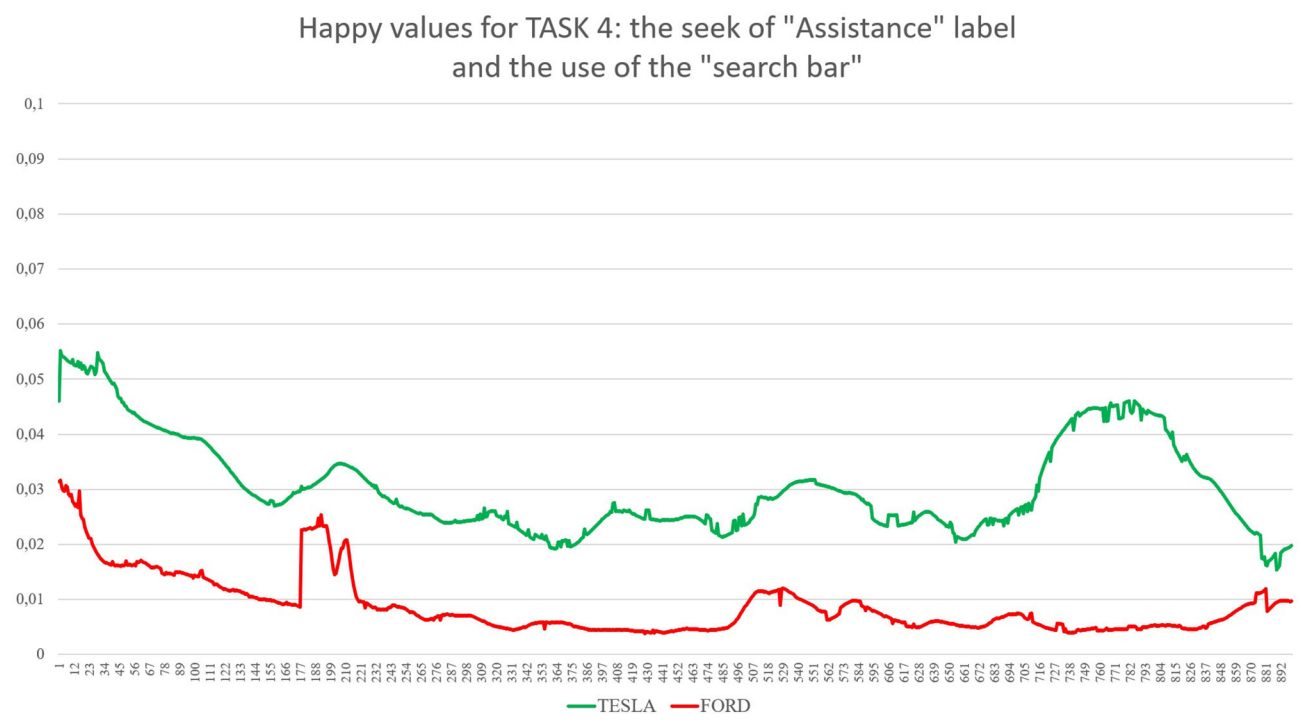

FIGURE 4 | The graph shows values for Happiness for both Tesla and Ford during Task 3 (subjects were asked to use the customising tool). On the X axis, time is expressed in 30 samples per second for a total of 900 samples, corresponding to 30 s as total maximum amount of time exposure to the websites for this task. On the Y axis, values of happiness are expressed between 0 (no happiness expressed by the face) and 1 (highest intensity of happiness expressed by the face).

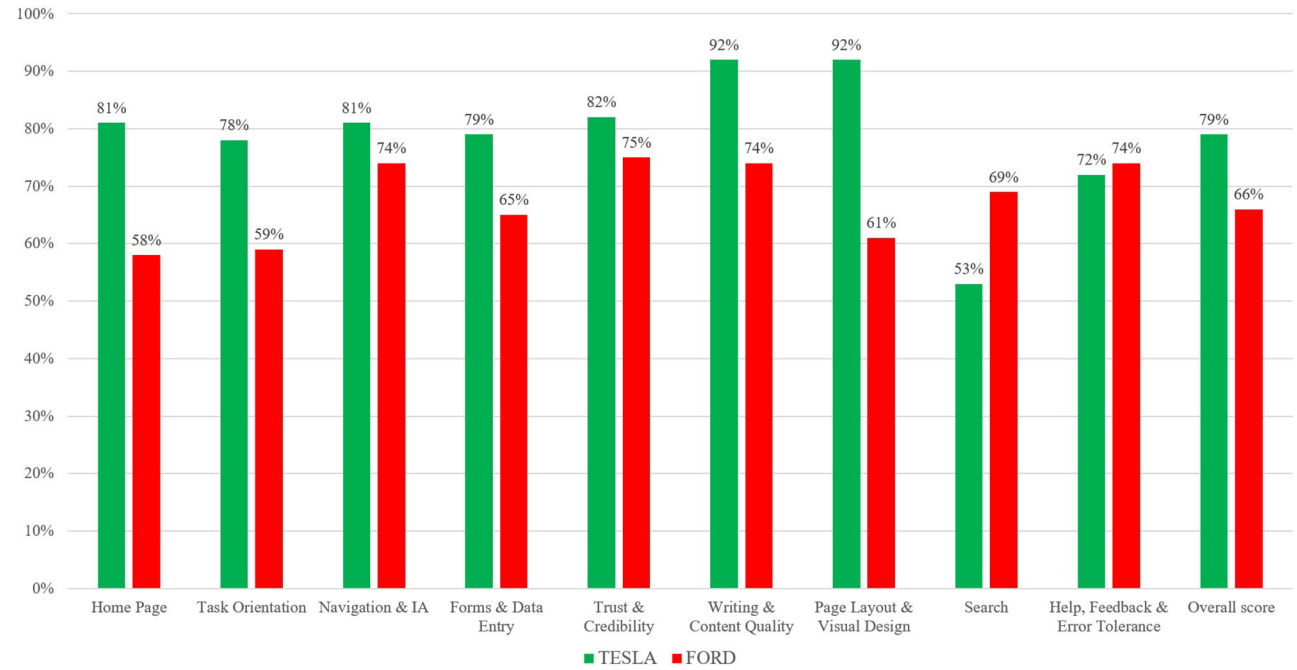

FIGURE 5 | Results from the heuristic evaluation analysis performed by five judges as professional experts in the field of User Experience (UX). The heuristic evaluation was performed in order to provide a qualitative evaluation about a traditional technique applied to assess UX; no statistical analysis was applied to the collected data. The overall scores show that the Tesla website provides a better UX in comparison with the Ford website (Tesla scored 79%, while Ford 66%). In particular, the dimensions of: "Home Page," "Writing and Content Quality," "Page Layout and Visual Design," and "Task orientation" show the highest gap between the two websites.

the homepages were used to provide the participants with a visual aid, and once again, they had to choose between a "yes" or "no" response in associating each item.

The participants were then asked to complete a five-item questionnaire with a Likert scale of 9 points. The following questions were asked: How did you evaluate the website that you navigated (from ≪0≫ = negative evaluation; to ≪9≫ = positive evaluation)? To what extent did you like the homepage of the website (from ≪0≫ = I did not like it at all; to ≪9≫ = I liked it a lot)? In your opinion, was it easy to find characteristics (such as max speed, acceleration, efficiency, etc.) and price (from ≪0≫ = very hard; to ≪9≫ = very easy)? Was it easy to use the car customisation tool (from ≪0≫ = very hard; to ≪9≫ = very easy)? Was it easy to find the search bar for customer service/assistance (from ≪0≫ = very hard; to ≪9≫ = very easy)?

Separate from the questionnaire, five expert professionals in the field of ergonomics and UX performed the heuristic evaluation from both websites (see **Figure 5**). This evaluation helps to identify usability scores in the following dimensions: Home Page (20 heuristics to evaluate the usability of the homepage, partially covering the sixth Nielsen principle "recognition rather than recall" and partially covering the fourth Nielsen principle "consistency and standard"), Task Orientation (44 items aimed to assess the ability of the website in supporting the tasks of users, covering the fifth Nielsen principle "Error prevention"), Navigation and Information Architecture (29 questions aimed to evaluate user navigation, correlating with the third principle from Nielsen's heuristics, "user control and freedom"), Forms and Data Entry (23 items, partially covering the fourth Nielsen principle "consistency and standard" and partially covering the fifth Nielsen principle "error prevention"); Trust and Credibility (13 items, partially covering the first Nielsen principle "visibility of status"), Writing and Content Quality (23 items, partially covering the second Nielsen principle "a match between system and real world"), Page Layout and Visual Design (38 items, covering the eight Nielsen principle "aesthetic and minimalist design"), Search (20 items, partially covering the seventh Nielsen principle "flexibility and efficiency of use"), Help, Feedback, and Error Tolerance (37 items, covering the ninth Nielsen principle "helping users recognise, diagnose, and recover from errors"). The heuristic evaluation portrays the qualitative assessment of UX by means of a well-established procedure (Nielsen and Molich, 1990) where each score is derived by a standardised procedure based on the answers to 247 questions, covering all the dimensions mentioned above, where professionals can choose one of the following "answers": "+1" (that means the website respects the guidelines), "−1" (the website does not respect the guidelines), and "0" (The website respects the guidelines in part only). These five expert professionals did not participate in the IAT pre- and post-test, and their facial expressions were not recorded.

TABLE 1 | The average values for Happiness and Confusion for both groups (Ford and Tesla) during the four navigation tasks.

	Task 1		Task 2		Task 3		Task 4	
Emotion	***Ford***	***Tesla***	***Ford***	***Tesla***	***Ford***	***Tesla***	***Ford***	***Tesla***
Happiness	**0.0112***	**0.0451***	**0.0117***	**0.0232***	**0.0114***	**0.0381***	**0.0104***	**0.0310***
Confusion	0.0098	0.0043	0.0088	0.0106	0.0139	0.0111	**0.0039***	**0.1001***

Values bolded with an asterisk indicate significant differences.

RESULTS

The main output of FaceReader classifies facial expressions from the participants according to intensity. Facial expressions are valued between 0 and 1, where 0 denotes an absent expression, and 1 indicates a fully present expression. FaceReader also calculates valence, which indicates whether the emotional state of each participant is positive (happy) or negative (sad, angry, or disgusted). Valence is equivalent to the intensity of positive expression minus the highest intensity of the three negative expressions. FaceReader calculated arousal, indicating whether the participant is active (+1) or not active (0). Arousal is based on the activation of 20 Action Units (AUs) of the Facial Coding System (FACS).

First, the *t*-test (two-tailed) on results related to the automatic detection of the facial expression of happiness as an emotional reaction during the navigation of the two websites showed significant differences between the two groups (see **Table 1**): for Task 1 (statistic $= -2.50$, $p = 0.015$), where Tesla elicited significant higher emotional expressions of happiness in comparison to Ford website during the exploration of the home page for the first 30 s; for Task 2 (statistic $= -2.51$, $p = 0.014$), where Tesla website showed higher induction of happier facial expressions in comparison to a website from Ford while users explored the characteristics of cars models, such as speed, acceleration, price, and so forth; for Task 3 (statistic $= -2.04$, $p = 0.046$), where Tesla website elicited higher emotional facial expressions of happiness in comparison to Ford website while user used the car-customising tool; for Task 4 (statistic $= -3.23$, $p = 0.002$), where Tesla website induced increased facial expressions of happiness in comparison to Ford website, while users searched for the information related to electric recharge of cars equipped with an electric battery pack. Additionally, the applied results show confusion as an emotional reaction during the exploration of both websites (Tesla vs. Ford). Concerning the automatic detection of facial expressions, the *t*-test showed significant differences between Tesla and Ford only for Task 4 (statistic $= -2.81$, $p = 0.008$).

Statistical analyses on reaction times were performed, as the first step, regarding the FoA. Descriptive statistics for both brands (Tesla vs. Ford) and relative associations (i.e., reliable, passion, comfortable, innovative, I would like to have it, electric, safe, traditional, and accessible) were calculated and reported in **Table 2** (for 80 subjects exposed to the Tesla website) and **Table 3** (for 80 subjects exposed to the Ford website). The dataset consisted of "Yes" answers from 160 participants,10 brand associations (i.e., reliable, passion, it makes me free, comfortable, innovative, I would like to have it, electric, safe, traditional, and accessible), and two brands (i.e., Tesla and Ford) recorded before website experience and after website experience. No significant results emerged from FoA dataset analyses.

TABLE 2 | Frequency of Associations (FoA) expressed in percentage of the number of "yes" answers over the total sample (80 subjects exposed to the Tesla website).

	Ford (Pre-test) (%)	**Tesla (Pre-test) (%)**	**Ford (Post-test) (%)**	**Tesla (Post-test) (%)**
Reliable	96	97	98	88
Passion	48	48	51	76
It makes me free	35	56	39	69
Comfortable	92	91	90	89
Innovative	35	96	38	99
I would like to have it	41	58	48	84
Electric	35	95	37	99
Safe	96	97	95	91
Traditional	91	13	95	9
Accessible	97	25	97	26

TABLE 3 | FoA expressed in percentage of the number of "yes" answers over the total sample (80 subjects exposed to the Ford website).

	Ford (Pre-test) (%)	**Tesla (Pre-test) (%)**	**Ford (Post-test) (%)**	**Tesla (Post-test) (%)**
Reliable	94	94	97	90
Passion	51	79	48	80
It makes me free	36	57	44	59
Comfortable	90	90	96	92
Innovative	34	93	55	94
I would like to have it	46	61	47	60
Electric	36	94	73	95
Safe	94	95	88	96
Traditional	95	11	87	10
Accessible	96	23	88	25

No differences between the group made by Tesla and Ford users were observed.

As a second step, statistical analyses were performed in the SoA: in this case, only the "Yes" answers were considered (when subjects choose "Yes" to express a positive association between a brand, either Tesla or Ford, and dimensions, namely: reliable, passion, it makes me free, comfortable, innovative, I

TABLE 4 | Strength of Associations (SoA) expressed in milliseconds of the number of "yes" answers over the total sample (80 subjects exposed to the Ford website).

	Ford (Pre-test)	Tesla (Pre-test)	Ford (Post-test)	Tesla (Post-test)
Reliable	2,269	2,323	**1,982 ($p = 0.046$)**	**2,099 ($p = 0.014$)**
Passion	2,361	2,314	2,166	2,182
It makes me free	2,327	2,459	**1,952 ($p = 0.039$)**	2,307
Comfortable	2,379	2,351	2,120	2,241
Innovative	2,358	2,139	**2,109 ($p = 0.031$)**	2,113
I would like to have it	2,419	2,297	2,198	2,167
Electric	2,534	2,187	**2,156 ($p = 0.021$)**	2,016
Safe	2,269	2,318	2,113	**2,155 ($p = 0.019$)**
Traditional	2,369	2,041	**2,165 ($p = 0.012$)**	1,943
Accessible	2,304	2,116	**2,211 ($p = 0.047$)**	1,956

Values in bold designate a significant difference between pre- and post-tests.

TABLE 5 | SoA expressed in milliseconds of the number of "yes" answers over the total sample (80 subjects exposed to the Tesla website).

	Ford (Pre-test)	Tesla (Pre-test)	Ford (Post-test)	Tesla (Post-test)
Reliable	2,201	2,361	**2,039 ($p = 0.043$)**	**2,157 ($p = 0.049$)**
Passion	2,269	2,591	2,061	**2,105 ($p = 0.029$)**
It makes me free	2,477	2,548	2,186	**2,218 ($p = 0.026$)**
Comfortable	2,282	2,351	2,187	**2,143 ($p = 0.032$)**
Innovative	2,279	2,322	2,245	2,130
I would like to have it	2,239	2,521	2,113	**2,124 ($p < 0.001$)**
Electric	2,083	2,105	2,264	2,007
Safe	2,247	2,349	2,097	2,098
Traditional	2,233	2,367	2,209	2,101
Accessible	2,196	2,313	2,309	2,109

Values in bold revealed a significant difference between pre- and post-tests.

would like to have it, electric, safe, traditional, and accessible). Before proceeding with the analysis, we removed outliers that were defined as response latencies below 300 ms and above 3,000 ms (Greenwald et al., 1998). No differences between the group made by Tesla or Ford users were observed. Outliers were identified and removed according to the threshold, which is typically employed with analysis involving reaction times. **Table 4** shows the SoA for the 80 subjects exposed to the Ford website, while in **Table 5**, the 80 subjects were exposed to the Tesla website. As a third step, *t*-test statistical analyses performed on SoA data from the *Ford* dataset for each association were examined; analyses revealed significant differences between pre- and post-test for the following associations: reliable, it makes me free, innovative, electric, traditional, and accessible (as shown in **Table 4**). As a fourth step, a *t*-test performed on SoA data from the *Tesla* dataset for each association was considered; results revealed significant differences between pre- and post-test for the following associations: reliable, passion, it makes me free, comfortable, I would like to have it (as shown in **Table 5**). As a fifth step of the analysis, a comparison has been considered between results from Ford and results from Tesla: the comparison shows that there are two associations shared by both brands: "reliable" and "it makes me free." However, the two brands differ regarding all other associations. The experience on the Ford website has been able to increase the associations of: "innovative," "electric" (these two are related to technological issues), "traditional" (related to the perception of a brand considered as a long-established presence in the automotive market), and "accessible" (perception of the Ford website as an experience enabling to convey information, allowing to evaluate the brand as more affordable); while the experience on the Tesla website has been able to increase the associations of: "passion," "comfortable," "I would like to have it" (all these three dimensions deal with emotional reactions: "passion," as a powerful feeling barely controllable by rational thinking; "comfortable," the Tesla website has been able to convey information related to a car that is more prone to providing physical ease and pleasant relaxation while using it; "I would like to have it" deals with the desire of owning that car, once again highlighting the feeling, worthy, or unworthy, that impels to the attainment or possession of something that is, in reality or in imagination, able to bring satisfaction and/or enjoyment).

Statistical analyses were performed on the collected data on the short survey exposed after the website navigation, in relation to the perception of both Tesla and Ford websites in terms of reaction time (the six items exposed were: "Trust and Credibility"; "Easy Navigation"; "Pleasant Visual Design"; "Promotion"; "Clear Information"; "Assistance"). The *t*-test showed a significant difference between the two groups (Tesla vs. Ford) for one item only: "Pleasant Visual Design," where the reaction time is faster for subjects who navigated the Tesla website in comparison to Ford (see **Table 6**). Finally, statistical analyses were performed in the last data collected concerning the short survey, exploring the judgments expressed by each participant who navigated the website about the navigation [the five items investigated were: "Do you like the website?"; "Do you like the Homepage?"; "Was it easy to find car characteristics and price?"; "Was it easy to use the customisation tool?"; "Was it easy to find assistance (use of the search bar)?"]; The *t*-test showed a significant difference between the two groups (Tesla vs. Ford) for all items (see **Table 7**). Results from heuristic evaluations performed by five different expert professionals show that, except for the dimension of "Help, Feedback, and Error Tolerance," where the two websites scored very similar values (74% for Ford and 72% for Tesla), and except for the dimension of "Search," where the Ford website scored on average a greater value in comparison to Tesla (69% for Ford and 53% for Tesla), all the other dimensions are showing, on average, a higher score

TABLE 6 | The final survey values (expressed in milliseconds) about reaction time expressed in milliseconds.

	Ford HP (Post-test)	Tesla HP (Post-test)
Trust and credibility	2,362	2,430
Easy navigation	2,314	2,352
Pleasant visual design	2,441	**2,171 ($p = 0.047$)**
Promotion	2,250	2,352
Clear information	2,263	2,198
Assistance	2,054	2,248

The reaction time is compared and analysed for each item. Values in bold indicate a significant difference.

TABLE 7 | Results from the final survey expressed by means of average scores for each item (from 1 to 9).

	Ford HP (Post-test)	Tesla HP (Post-test)
Do you like the website?	6.5	**7.3 ($p < 0.001$)**
Do you like the Homepage?	6.4	7.9 **($p < 0.001$)**
Was it easy to find car characteristics and price?	6.0	**6.9 ($p = 0.022$)**
Was it easy to use the customisation tool?	6.1	7.2 **($p < p < 0.001$)**
Was it easy to find assistance (use of the Search bar)?	7.4	3.7 **($p < 0.001$)**

Values in bold revealed a significant difference between the two groups (80 subjects navigated Ford website and 80 subjects Tesla website). At the end of website navigation, all subjects were asked to fill in a brief online questionnaire, providing their responses by means of a 9 point Likert scale (from 1 = "not at all"; to 9 = "A lot"). For instance, the first question is: "Do you like the website?". Subjects who navigated the Ford website scored on average 6.5 on a 9 points Likert scale, while the 80 subjects who navigated the Tesla website scored on average 7.3 on the same 9 points Likert scale: there is almost one point of difference, revealing a significantly higher level of satisfaction for Tesla website in comparison to Ford website.

for Tesla in comparison to the Ford website (see **Table 8**); in particular, the highest difference is for the dimension of "page layout and visual design" (where Tesla scored, on average, 92% while Ford 61%); "Home Page" (where Tesla scored, on average, 81% while Ford 58%); "writing and content quality"(where Tesla scored, on average, 92% while Ford 64%); "task orientation" (where Tesla scored, on average, 78% while Ford 59%). The overall scores from heuristic evaluations indicate that the Tesla website seems to provide an overall better UX in comparison to the Ford website (Tesla scored 79% while Ford 66%).

DISCUSSION

The aim of this study was to examine whether the use of automatic facial emotional expression analyses and reaction time methods may broaden the assessment of UX in young adults by using novel integration of techniques that combine a variety of approaches based on self-report and heuristic evaluation coupled with software both for emotional facial detection and reaction time measurements recorded by means of an online quantitative procedure only. Data analysed indicated that the

TABLE 8 | Results from heuristic evaluations expressed by means of average percentage scores for each dimension (in bold, the highest differences between the two website average scores).

	Ford (%)	Tesla (%)	Difference (%)
Home page	**58**	**81**	**23**
Task orientation	**59**	**78**	**19**
Navigation and information architecture (IA)	74	81	07
Forms and data entry	65	79	14
Trust and credibility	75	82	07
Writing and content quality	**74**	**92**	**18**
Page layout and visual design	**61**	**92**	**31**
Search	**69**	**53**	**16**
Help, feedback and error tolerance	74	72	02
Overall score	66	79	13

two groups, each exposed to one of the two websites of well-known American brands in the automotive industry, reacted in a significantly different way for all the methods considered. The Tesla website has been able to induce a stronger emotional reaction, according to all results. In terms of facial expressions, it elicited much higher expressions of happiness in all the tasks performed. Taking into account the results from heuristic evaluation where average scores for "web layout and visual design" and "homepage" are higher for the Tesla website in comparison to the Ford website, and taking into account results from the self-reports from all the participants enrolled in the research projects, showing significant differences in favour of the Tesla website in comparison to the Ford website, together with time reaction analyses for the item "Pleasant Visual Design" from the survey that displays significant faster response for the Tesla website, it is possible to claim a greater emotional impact played by the Tesla website in comparison with Ford. This pattern of better emotional performance is also supported by semantic dimensions investigated through reaction time technique too: they show that respondents perceived the Tesla website as conveying information, enabling to change implicit attitudes for "reliable," "passion," "freedom," "comfortable," and "desire to own it." Taken altogether, all these dimensions are more related to emotion rather than functions or information about car performances and prices. At the same time, results show how participants are convinced Tesla is not a traditional brand and they do not believe it is an accessible car (as there are no significant differences for those two dimensions).

On the opposite, results from FORD show a less important emotional impact, not only in terms of facial expressions related to happiness, always at a lower level in all tasks accomplished on the FORD website but also for all other techniques considered. Heuristic evaluation from five expert professionals in the field or UX showed, on average, a decreased score (with the exception of the items of "Search" and "Help, Feedback, and Error Tolerance") for the FORD website in comparison with the TESLA website. The final survey showed significantly decreased Likert scale scores for all items in comparison with FORD, except for the "Search bar" (we will consider that specific issue later here in this section). Finally, the dimensions investigated by means of

reaction time analyses reveal that FORD websites have been able to convey information enabling to change implicit attitudes for "reliable," "freedom," "innovative," "electric," "traditional," and "accessible." Except for the dimension of "freedom," all other items are more related to information cognitively conveyed by the website: innovation, and electric are the best examples, as the FORD website shows the latest innovation regarding the technology implemented in some models and the "electrification process" started by the company developed few hybrid models; in addition, in Task 3, the participants had to look for a model, the "Mustang Bullitt," which also presented a version of a car model that is completely electric (the only one from FORD panorama of car models). The dimensions of "Traditional" and "Accessible" are more related to the general brand perception of an automotive organisation that appeared in the market a long time ago and to provide much more affordable models in comparison to Tesla, even if the models selected within tasks accomplished by experimental subjects were chosen according to a similar placement (a similar price range).

Considering the specific case represented by Task 4, it is possible to evaluate the emotional impact played by two different design choices more related to "information architecture." TESLA shows the button "Assistance" as the 11th label of a vertical menu completely hidden in a hamburger menu located on the top-right side of the homepage: a user has to identify it (he/she has to know or understand that the three small horizontal lines on the top-right of the homepage are a sort of a small icon that represents a so-called "hamburger menu," enabling to explode a menu only once requested) and click to open it on the right side of the screen. FORD shows the same call to action directly in the upper side of the homepage, as the fourth label of a horizontal menu composed of four labels in total, where the label "Assistance" is available at a first look. Data collected show which one of the two design solutions is preferable for users; this time, FORD seems to perform much better in comparison with TESLA. The heuristic evaluation average scores show better results for this specific function, and the survey brings a significant positive preference for FORD in comparison to TESLA. Facial expressions are presenting mixed findings: on one side, facial expressions in terms of happiness are always much higher for TESLA, also for Task 4. On the other side, confusion, one of the three new affective attitudes released by FaceReader 8.1, is showing significantly higher values for TESLA in comparison to FORD, detecting the negative impact raised by the seek for the "Assistance" label and the mental efforts to find it. It may be possible to explain the gap between these two outputs from automatic facial expressions analysis because happiness is a more general emotional reaction in comparison to confusion (Rozin and Cohen, 2003; Grafsgaard et al., 2011): happiness enrols a greater number of AUs and lasts for a shorter time in comparison to confusion, an affective state that shows up for 2 up to 5 s. These findings can also be explained through the strong customer-brand relationship that follows under the concept of brand love (Huber et al., 2016) that is "*the degree of passionate, emotional attachment a consumer has for a particular trade name*" (Carroll and Ahuvia, 2006). Trivedi and Sama (2020) categorised several antecedents of brand love, such as brand trust, CX, psychological attachment, and hedonic value of the brand, identifying how brand love is a strong indicator of a customer's affective response to the brand during the CX (Roy et al., 2013; Trivedi, 2019; Trivedi and Sama, 2020). Therefore, a possible interpretation of our results can rely on the moderation effects of brand love for TESLA, as shown by the ranking provided by Interbrand (https://www.rankingthebrands.com) where TESLA has been able to gain 59 positions in 2020 in comparison to FORD, whose position raised only 20 points. Overall, the design of the two websites seems to raise different emotional impacts: the TESLA website takes advantage of much more pictures and visual elements, as well as of colours and "3D virtual tours" that may represent one of the key elements, enabling a general greater emotional impact. For instance, considering now Task 2, subjects were instructed to look for the Tesla "Model X." We choose, by purpose, this model, as the landing page of this model, once loaded by the internet browser, showed in the upper part of the page a "3D virtual tour" of the car from the front to the rear, with the peculiar doors opening like two "wings" of a seagull: the "3D virtual tour," lasting 5 or 6 s and automatically starting once the webpage was opened, raised quite a big effect in terms of emotional reactions (see graph in picture 3 or the Results section, where the level of happiness is much higher in comparison to FORD, especially in the beginning part of the task, when actually, the participants were exposed to the "3D virtual tour" described). For the FORD website, where the model was asked to look for the "New Explorer," this car model was presented by means of a landing page with classic pictures, videos (that could start only after clicking; thus, they could be considered as additional pictures with the "play icon" in the middle, as none of the participants decided to start a video) and longer text sections in comparison to the TESLA landing page. All emotional effects from these distinct elements and layouts are detected by the different levels of happiness showing up on the faces of the participants.

Aside from the specific web contents and "information architecture" styles and designs, the aim of the present research project was to show how emotional impact played by websites can be assessed by neuromarketing techniques such as automatic facial emotion detection, coupled with reaction time methods, which no previous research tried to investigate. With this work, it is possible to show how these techniques can be efficiently applied to website evaluation and widening insights to understand and assess UX.

CONCLUSION

In our study, the data collected by means of automatic facial emotional expressions during website exploration and implicit association techniques applied before and after web navigation evidenced how different design solutions to shape UX. Moreover, it shows how the integration of neuromarketing techniques with traditional ones may enhance the understanding and evaluation of UX. These findings may

have implications for developing new protocols for the user and usability testing.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, with the permission of the companies (SR LABS and NEUROHM) that contributed to the research project realisation.

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

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

ACKNOWLEDGMENTS

We thank all the participants in our study, as well as SR LABS (https://www.srlabs.it), NEUROHM (https://neurohm.com), Allegheny College, and the Catholic University of Milan. We finally want to thank Allegheny College students Victoria Vradenburg and Danae Fowler for the literature and research support, and the students from the Catholic University of Milan (Elisa Di Pietro, Giordana Iannuzzi, Giulia Bragaglio, Giulio Roberto Varrà, Laura Cappello, and Marta Fortusini) that helped with the gathering of all data collected.

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ORIGINAL RESEARCH
published: 14 October 2021
doi: 10.3389/fpsyg.2021.688713

Consumer Neuroscience: Attentional Preferences for Wine Labeling Reflected in the Posterior Contralateral Negativity

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Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *31 March 2021*
Accepted: *13 September 2021*
Published: *14 October 2021*

Citation:
Alvino L, Constantinides E and van der Lubbe RHJ (2021) Consumer Neuroscience: Attentional Preferences for Wine Labeling Reflected in the Posterior Contralateral Negativity. Front. Psychol. 12:688713. doi: 10.3389/fpsyg.2021.688713

During the decision-making process, consumers notice, inspect, and visually scan different products. External characteristics of a product, such as design, packaging, label, and logo, have been shown to strongly influence how customers perceive, assess, and select a product. Marketers have put a lot of effort into determining the factors that trigger consumers' visual attention toward products, using traditional research methods, self-reports, or observations. The use of neuroscientific tools to study consumer behavior may improve our understanding of how external characteristics influence consumers' visual attention. Consumer neuroscience research shows that preferences for a product may already be reflected in brain activity before customers make a final decision. Using electroencephalography (EEG), we investigated whether the design of different wine labeling influences individual preferences, reflected in the neural activity related to visual attention. More specifically, we examined whether the posterior contralateral negativity (PCN) can be used to assess and predict consumers' preferences for a specific product based on its external characteristics. The PCN is commonly used to estimate attentional selection by focusing on stimulus-side dependent EEG lateralization above parieto-occipital areas. We computed the PCN to assess whether a certain wine label caught participants' visual attention and additionally by comparing the PCN with behavioral data (wine preferences and reaction times) to determine whether early effects of visual attention could predict participants' final preferences for a specific label. Our findings indicate that the PCN provides relevant information on visual attention mechanisms for external characteristics, as the view of the four labels modulated PCN amplitude. We hope this study can help researchers and practitioners in examining the effects of external product characteristics on consumer choice by estimating the changes in the EEG that are related to visual attention.

Keywords: consumer neuroscience, neuromarketing, EEG, visuospatial attention, extrinsic cues, posterior contralateral negativity, N2pc, wine labeling

INTRODUCTION

A product's external characteristics (or extrinsic cues) refer to any product features that can be manipulated without changing the essential attributes of the product (Olson and Jacoby, 1972; Veale and Quester, 2009; Jaafar et al., 2012; Yan et al., 2019). In marketing, external characteristics (e.g., brand, label, country of origin, and price) are often used to positively influence the consumer's product quality perception (e.g., being cheap or expensive, hedonic or utilitarian, and safe or unsafe) (Veale and Quester, 2009; Abdullah et al., 2013; Spence, 2016; Ardeshiri and Rose, 2018; Yan et al., 2019). Studies suggest that consumer preferences for a product can be strongly influenced by its external characteristics (Pechmann and Ratneshwar, 1992; Lans et al., 2001; Lange et al., 2002; Bredahl, 2003; Veale and Quester, 2009). Researchers identified three conditions in which consumer preferences for a product are strongly affected by its external characteristics: (1) when consumers are not familiar with the product (2) when consumers do not have access to the internal attributes of the product, and (3) when consumers do not have enough knowledge to assess the quality of a product (Zeithaml, 1988; Underwood et al., 2001; Mueller and Szolnoki, 2010; Risius et al., 2019). Thus, the product external characteristics are very important in situations where the product is unknown to the consumer, or consuming the product is not possible before purchasing it and when assessing product quality is directly related to the consumers' expertise about it. This condition is very common for beverage products, like wine. Research suggests that most wine consumers are forced to choose the wine based on its external characteristics (Tang et al., 2015).

Consumers might face one or more of the above-described situations while purchasing a bottle of wine: Consumers might not know the type of wine they are purchasing, they might be exposed to a large product assortment, and in most cases, it is not possible to taste the wine prior to purchase (Tang et al., 2015). They might also lack the knowledge on how to assess the quality of wine, even if they can taste it. Literature suggests that the label is among the most important external characteristics for wine choice (Thomas and Pickering, 2003; Goodman et al., 2005; Grunert, 2005; Cohen, 2009; Tang et al., 2014, 2015; Latiff et al., 2015). Wine labels are known to strongly influence consumer preferences and purchase decision-making (Thomas and Pickering, 2003; Grunert, 2005; Mueller and Lockshin, 2008; Orth and Malkewitz, 2008; Cohen, 2009; Latiff et al., 2015; Tang et al., 2015; Barwich, 2017). Gluckman (1986) identified that consumers perceive wine labels as one of their primary sources of information. Consumers rely on the label to collect important information about the wine, such as its country of origin, grape variety, year of production, and producer (Tootelian and Ross, 2000; Lange et al., 2002; Thomas and Pickering, 2003; Goodman et al., 2005; Hall and Mitchell, 2008; Tang et al., 2015).

Beyond the legal requirements that must be printed on a label for the product to be sold, the design of a label can suggest and communicate a lot of information about a wine. It can make the wine look expensive (even if it is not), appear fresh, and modern, or suggest a certain taste. In many cases, the label design and information provided offers reassurance that the wine will provide value for money in terms of performance and quality (Thomas and Pickering, 2003; Barber et al., 2006, 2007). Two important classifications of wine label designs are the "traditional" and the "modern/contemporary" labels (Batt and Dean, 2000; Boudreaux and Palmer, 2007; Hall and Mitchell, 2008; Elliot and Barth, 2012; Larson, 2012). Elliot and Barth (2012) noted that in the United States, modern, innovative, and distinctive labels are more attractive to younger consumers compared to the older consumers (who prefer more traditional styles). Other studies suggest that French consumers, whether young or old, novice or expert, still prefer wine with traditional labels in order to reduce perceived risk (Celhay and Trinquecoste, 2015).

Marketers often use techniques like observation, focus groups, and questionnaires to study consumers' preferences for wine labels (Lange et al., 2002; Barber et al., 2006; Elliot and Barth, 2012; Celhay and Trinquecoste, 2015). However, traditional marketing techniques cannot always give an accurate and objective understanding of consumer behavior during wine selection (Ariely and Berns, 2010; Babiloni et al., 2014; Alvino et al., 2018, 2019b). In recent years, the rapid advance in neuroscience research has made it possible to use neuroscientific tools for business purposes. The use of neuroscientific techniques and tools for marketing purposes is known as Consumer Neuroscience or Neuromarketing.[1] In our paper, the term Consumer Neuroscience is preferred. Consumer Neuroscience helps both researchers and practitioners to investigate how cognitive processes originate in the brain and identify the brain areas involved in the explication of cognitive functions underlying marketing-relevant behavior (Alvino et al., 2020). Consumer Neuroscience research addresses marketing-related issues such as advertising, branding, product experience, online experience, product development, and product pricing (Clement et al., 2017; Alvino et al., 2019a, 2020; Ma et al., 2019a,b; Sung et al., 2019; Ciceri et al., 2020; Fan et al., 2020; Hu et al., 2020; Yu et al., 2020; Liu et al., 2021).

Consumer Neuroscience can help companies to design and develop more successful and desired products by studying consumers' physiological and neurophysiological responses to a product's external characteristics, such as a label. Attention can be defined as the ability to focus on certain aspects of the environment while ignoring other information (Venkatraman et al., 2015). In particular, attention in the market field is the degree to which consumers focus on a stimulus, a prerequisite for information processing and, therefore, a key step in the consumer's decision-making process (Varela et al., 2014; Krucien

[1]In the literature, we find different classifications of Neuromarketing and Consumer Neuroscience research (Lee et al., 2006; Hubert and Kenning, 2008; Plassmann et al., 2010; Ramsøy, 2014). Consumer neuroscience research can be defined as the study of neuropsychological mechanisms that support and lead consumer decision making and behaviour (Alvino et al., 2020), while Neuromarketing is the application of neuroscientific methods for conducting company-specific market research (Hubert and Kenning, 2008). Thus, Consumer Neuroscience is considered as a scientific approach, while Neuromarketing is the application of Neuroscience methods to sell products.

et al., 2017; García-Madariaga et al., 2019). As a consumer's attention toward a product is reflected in the neural processing of visual stimuli (Stasi et al., 2018; Alvino et al., 2019b; Karmarkar and Plassmann, 2019), studying the allocation of visual attention might help to define how a product's external characteristics are processed in the brain. According to Clement et al., 2017), visual attention is a key component in consumers' decision-making process since information must be visually noticed to influence choice. Similarly, studies suggest that product preferences at least partially depend on the amount of attention that they receive during the decision-making process (Krajbich et al., 2010; Glimcher and Fehr, 2013; Chen et al., 2019). Consumer Neuroscience studies have investigated changes in consumer's visual attention mechanisms related to different label characteristics (e.g., attractive vs. unattractive and presence of sustainability information), type of ingredients used (earthworm flowers vs. grain crackers), visual elements of the wine labeling (e.g., text vs. images and different design), and consumer knowledge about wine (non-expert and expert wine drinkers; Russo, 2015; van Loo et al., 2015; Laeng et al., 2016; Khachatryan et al., 2017; Russo et al., 2020). Except for the study of Russo et al. (2020), all these studies were conducted using eye tracking (ET) as the main research method.

Eye tracking has been widely used in consumer neuroscience research to study visual behavior (e.g., point of fixation, gaze, and pupil dilatation), customers' visual attention mechanisms, and consumers' engagement (Alvino et al., 2020). However, the literature suggests that the measurement of eye movements is not always sufficient to understand how consumers focus their attention, for instance why a label catches consumers' attention. In fact, eye movements are discrete events (limited to visual or written language comprehension). Several authors suggest that eye movements are partly dependent on higher cognitive processes (Rayner, 2009; Luck and Kappenman, 2011; Rayner et al., 2015; Rayner and Reingold, 2015; Luke et al., 2018). This makes eye movements also relatively slow compared to other mechanisms (e.g., brain activity) (Luck and Kappenman, 2011). For instance, when reading text, eye movements are influenced on a moment-by-moment basis by a variety of linguistic factors, such as word frequency, predictability, and syntactic complexity (Rayner, 1998, 2009; Rayner and Reingold, 2015; Luke et al., 2018). Thus, eye movements are often a consequence of cognitive processes that may already be reflected in ongoing brain activity before the actual eye movement is executed.

As most cognitive processes occur within tens to hundreds of milliseconds (Freeman and Quiroga, 2012; Cohen, 2014), it is possible that consumer neuroscience tools that identify and analyze brain activity are more effective in studying the visual allocation of attention mechanisms and individual preferences. Literature suggests that electroencephalography (EEG) is a suitable tool to measure visual attention mechanisms. EEG is a non-invasive brain imaging method that detects brain electrical activity using different electrodes placed on the scalp (Abhang et al., 2016; Alix et al., 2017). EEG has an excellent temporal resolution (Burle et al., 2015; Bilucaglia et al., 2020); thus, it can capture the dynamics of brain processes in the time frame in which they occur (Freeman and Quiroga, 2012; Cohen, 2014). EEG is well suited to capturing the fast, dynamic, time sequenced cognitive events underlying the visual allocation of attention (Cohen, 2014). This permits the identification, within a functional time window, of neurophysiological correlates of the exposure to marketing stimuli, such as external cues (e.g., labels, packaging design) (Bazzani et al., 2020). Studies show that changes in electrophysiological measures can be useful for examining the perceptual and cognitive processes that occur in response to marketing stimuli (Ma et al., 2019a,b).

To study whether individual preferences for different wine labeling are related to the allocation of visual attention, we focused on changes in the posterior contralateral negativity (PCN). Parameters of the PCN[2] are analyzed in order to assess whether a certain bottle/label caught visual participants' attention. The PCN is "*an established electrophysiological marker for examining (millisecond-by-millisecond) the deployment of focal attention in visual space*" (Töllner et al., 2012; pp 1556). Parameters of the PCN reflect the dynamics of visuospatial attention processes and provide a reliable and valid temporal measure of target localization (Geyer et al., 2010; Töllner et al., 2011; Vossel et al., 2014). The PCN expresses an increased negativity above visual brain areas (posterior electrodes) contralateral to the stimulus position in a time window of approximately 175 and 300 ms (or even less) after the stimulus presentation. This parameter can be used as a marker that traces the transition from when the stimulus (e.g., a label) reaches a receptor (e.g., retinal cell) to the focal attentional stage to target selection, thus when the stimulus is perceived and successively selected (Töllner et al., 2011). Numerous psychological and neuroscientific studies used the PCN in order to examine how the timing and the allocation of visuospatial attention is modulated by stimulus intensity, stimulus saliency, aging, and set size (Van der Lubbe et al., 2001; Van der Lubbe and Verleger, 2002; Geyer et al., 2010; Töllner et al., 2011; Vossel et al., 2014).

Based on the aforementioned considerations, our study aims to *investigate whether changes in the brain activity and individual preferences for wine labeling*[3] *is related to the allocation of visual attention.* To achieve our aim, we carried out a laboratory experiment using EEG. During the experiment, thirty-one volunteers were exposed to four different examples of wine labeling, in pairs of two, which were presented on the left and right side of a computer screen. We used a within-subjects design and carried out the experiment in two sessions. Participants were asked to select the preferred wine labeling (by pressing a button on the corresponding side) while their electrical brain activity was recorded.

[2]Other studies often use the term N2-posterior contralateral (N2pc); however, here we prefer the term PCN as the posterior contralateral negativity is not necessarily related to the N2 component.

[3]In this study, the wine labeling refers to both the front wine label design and bottle shape, as reported by Elliot and Barth (2012) and Laeng et al. (2016).

The current study adds to previous research by investigating whether the PCN can be used to assess and predict consumers' preferences for wine labels.

METHODOLOGY

Participants

Before the experiment, participants were asked to fill in a questionnaire about their drinking habits, their wine knowledge, and the Alcohol Use Disorders Identification Test (AUDIT). Both questionnaires and the AUDIT test were sent by email. We used the AUDIT to assess whether volunteers could participate in our experiment. This test identifies participants who display hazardous (or risky) drinking behavior, harmful drinking, or alcohol dependence. Participants with a score higher than 19 in the AUDIT were excluded as they can be considered to abuse alcohol, which may lead to deviant results (Lacoste-Badie et al., 2020). Two subjects were not invited to join the experiment as they score was higher than 19. All selected participants had a score lower than 18.

EEG was recorded from thirty-one participants. The participants were all volunteers, so they did not receive an incentive to participate in this study. Participants were mostly students and/or employees of the University of Twente (The Netherlands). The study was evaluated by the ethical committee of the BMS faculty and was carried out in line with the declaration of Helsinki.

When participants arrived at the laboratory, they were also tested for handedness and color blindness. We used Annett's Handedness Inventory (Annett, 1970) to test handedness as this is an important factor in the investigation of brain lateralization (van Strien, 1992, 2003). The handedness test revealed that twenty-eight participants were right-handed, and three participants were left-handed. Several studies suggest that color vision deficiency (CVD) is one of the most common types of vision deficiency (Ekhlasi et al., 2021). In this experiment, participants were asked to assess the preferences for wine labeling with different designs and colors. We tested participants' possible defects of color vision using the Ishihara test (Birch, 1997). The test consists of a number of colored plates, namely, Ishihara plates, each of which contains a circle of dots appearing randomized in color and size (Birch, 1997; Ekhlasi et al., 2021). Participants were asked to report the colored numbers in the figures. All participants had normal color vision.

Six participants were excluded from the original sample for different reasons. For two participants, a different amplifier was used in the second as compared to the first session, due to EEG equipment failure. Two participants were not able to take part in the second session. Two other participants were excluded because of excessive artifacts in their EEG recordings. The final sample consisted of twenty-five participants between 18 and 40 years of age ($M_{age} = 26.4$, $SD = 4$). In total, ten participants were female ($M_{age} = 28$, $SD = 5$, ranging from 23 to 39 years) and fifteen participants were male ($M_{age} = 25.5$, $SD = 3.1$, ranging from 19 to 31 years). All volunteers had no history of neurological illness or damage, were not using drugs or psychiatric medication, and had normal or corrected-to-normal vision and no color blindness. Participants' knowledge of wine was based on self-report. Only participants with no knowledge or little knowledge of wine were selected to take part (Bruwer and Li, 2007; Laeng et al., 2016). Based on the questionnaire's results, eleven participants could be considered as inexperienced, while fourteen participants displayed basic knowledge. Participants had no prior knowledge of the wines presented during the experiment.

Procedures and Task

When participants arrived at the laboratory, they were asked to sign an informed consent form. Participants received detailed written and verbal instructions on all the tasks they were going to perform in the experiment. The volunteers were invited to sit in a comfortable chair, and EEG electrodes were applied. The room was sound-attenuated and illuminated. Participants were placed at a distance of approximately 100 (cm) at the eye level in front of a 24-inch AOC G2460P LED computer screen. Participants were asked to relax and to reduce sudden movements and blinking in order to prevent distortion of the EEG signal. An experimenter sat nearby throughout the experiment to check the procedure and to answer any questions.

The experimental design was set up considering repeated measurements (within-subject design). In a within-subject design experiment, each individual is exposed to more than one of the treatments being tested, whether it be playing a game with two different parameter values, being treated and untreated or performing tasks under more than one external stimulus (Charness et al., 2012). These experiments are more naturally aligned with most theoretical mindsets. For instance, a theorist is likely to imagine an agent in a market reacting to a price change, not two agents in separate markets with different prices (Charness et al., 2012). In this experiment, participants took part in two sessions (*Session 1* and *Session 2*), which were separated by 2 weeks. A time frame of 2 weeks was chosen in order to reduce the possibility that volunteers would remember the preferences indicated for each wine but at the same time examine the consistency of their preferences.

The study employed a "Stimulus Discrimination" task that required a right-hand or left-hand button press in response to the presentation of a set of two wine bottles/labels. Participants were instructed to press the key on the side that corresponded with the label/bottle they preferred. Responses were made on a standard QWERTY keyboard, with the left index finger positioned on the "left Ctrl" key, and the right index finger on the "right Ctrl" key. Stimulus presentation was controlled by Presentation software (Neurobehavioral Systems, Inc., 2012).

Each participant completed ten practice trials to get familiar with the task before the real experimental phase. As shown in **Figure 1**, each trial began with a white fixation point appearing in the center of the computer screen, followed by an interval of 3000 ms before the white fixation point turned red (for 200 ms). Then, a pair of bottles/labels was presented on the screen for 800 ms and the participants could choose the preferred bottle/label. Participants could freely decide (1) when to press one of the two buttons (no time limit) and (2) whether they wanted to press the right or the left button.

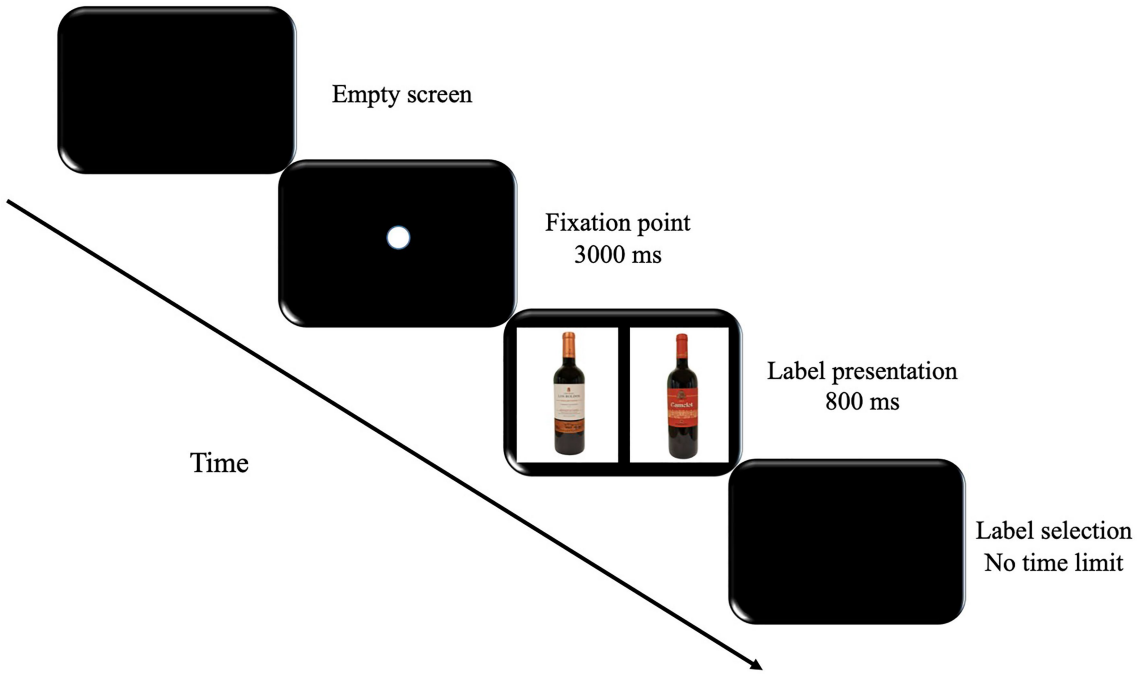

FIGURE 1 | Experimental procedure. Participants were asked to choose the preferred wine after viewing the labeling presentation.

The stimulus discrimination task was divided into four blocks, and the participants had 1 min of rest at the end of each block. The blocks contained 96 stimuli each. Overall, the participants saw a succession of 384 sets of pictures of four different examples of wine labeling. The average duration of the task was between 42 and 47 min, including a time break between the blocks.

Stimuli

The pictures of four examples of wine labeling were used as stimuli. The wines were selected based on the type of grape, price, country of origin, and label. The wines selected had the same type of grape (Cabernet Sauvignon, 100 percent) but a different country of origin (Chili and Italy). The wines were in a low-to-moderate price range (€3–€27; Boudreaux and Palmer, 2007). Two wines were moderate-priced wines (price category: €24–€27), while the two other wines were low-priced wines (price category: €3–€5). The prices were compared on the same website to have a realistic evaluation of the wines. All the wines can easily be bought online. For simplicity, we divide the wines into Cheap (C: €3–€5) and Expensive (E: €24–€27).

Marketing literature suggests that wine label design could be classified as either "traditional" or "modern/contemporary" (Batt and Dean, 2000; Boudreaux and Palmer, 2007; Hall and Mitchell, 2008; Elliot and Barth, 2012; Larson, 2012). Based on previous studies, the labels were selected according to specific patterns hue and color (dark or bright), images (e.g., chateaux or animal), different writings (white, black, or gold), bottle shape (standard shape or odd shape), and overall design (simple or complex; Batt and Dean, 2000; Boudreaux and Palmer, 2007; Elliot and Barth, 2012; Sáenz-Navajas et al., 2013). As shown in **Figure 2**, the two Chilean wines had a simple and traditional label, and for both wines, the type of wine and the production year was clearly written in the middle of the label. In particular, the label of the Chilean Expensive (CE) wine was white and bronzed, with a vineyard drawn at the bottom of the label. The country of origin was written in small characters. The Chilean Cheap (CC) label was white with blue sides; the name of the wine was written in gold characters, and the bottle had a plastic cork. Both the production year and country of origin were visible on the label. Overall, the two labels had an old heritage style (Elliot and Barth, 2012). The label of the two Italian wines had a more modern design. Both labels had contemporary fonts, abstract forms, bright color (red), and asymmetrical shapes. The label of the Italian Expensive (IE) wine was red with gold and white characters. The production year, the names of both wine and producer were clearly visible. The label had a golden drown of warriors to revoke the name of the wine. The label did not show the country of origin. The Italian Cheap (IC) label was white and red, and small red patterns were presented. However, the bottle had a peculiar shape, different from the other wines (Boudreaux and Palmer, 2007; Elliot and Barth, 2012). The country of origin, type of wine (Cabernet Sauvignon) was also visible (Elliot and Barth, 2012).

The wine bottles were photographed using a NIKON D3300 camera. The bottles were positioned on a white backdrop, and they were illuminated with different daylight bulbs to balance the pictures (the labels were comparable in size and luminance). Adobe Photoshop CC (2015) software was used to erase the background and regulate the size and luminance. The four

FIGURE 2 | Experimental stimuli (Wine bottles and labels). Chilian Expensive **(A)**, Italian Expensive **(B)**, Chilean Cheap **(C)**, and Italian Cheap **(D)**.

pictures were stored as 300-pixel JPEG files. Images were displayed aligned vertically in the center of the screen (as shown in **Figure 1**). Finally, the stimuli were digitally presented on a 24-inch monitor.

Behavioral and EEG Data Acquisition and Analysis

The EEG was recorded continuously from 32 active Ag/AgCl electrode (wet electrodes) sites using an EasyCap-62 channel cap (standard international 10–20 system layout) connected to an ActiChamp amplifier, with BrainVision Recorder software (version 1.21.0102). The electrodes were located at the following sites: AFz, AF3, AF4, AF7, AF8, F1, F2, F5, F6, FCz, FC3, FC4, FT7, FT8, C3, C4, C5, C6, CPz, CP3, CP4, TP7, TP8, P1, P2, P5, P6, POz, PO3, PO4, PO7, and PO8. The horizontal and vertical electro-oculogram (hEOG and vEOG) were also recorded. Two electrodes were placed at the side of both eyes to measure the electrical activity generated by horizontal eye movements. Electrodes located on the infraorbital and supraorbital regions of the left eye placed in line with the pupil enabled to measure vertical eye movements and blinks. The resistance of the electrodes was kept below 10 kΩ by using electrode gel and standard procedures to improve conductivity.

EEG data were analyzed with BrainVision Analyzer v. 2.1.1 software. The continuous data were epoched from 500 ms prior up to 2500 ms after presenting the stimuli (wine bottles/labels). An initial baseline was set from −100 to 0 ms before presenting the stimuli. EEG was corrected for eye movement-related artifacts *via* artifact rejection and Ocular Correction ICA (Independent Component Analysis). Trials with amplitude differences exceeding ±50 μV on the hEOG channel and ± 100 μV on the vEOG channel were marked to remove segments with horizontal eye movements and eye blinks from 200 ms before until 200 ms after presenting the stimuli. This procedure left on average 79.5% ($SD = 15.8\%$) of the presented trials per participant. After the Ocular Correction, another artifact rejection was applied (criteria were set to remove trials with differences of more than ±150 μV, a gradient criterion of 50 μV/ms, and a low activity criterion of 0.1 μV for 50 ms). EEG channels with artifacts were marked and were not included in the data analysis. Finally, lateralized EEG potentials as a function of the to-be- attended side (details below) were determined for all homologue electrode pairs and labels.

During the experiment, two wines were presented simultaneously on the computer screen, one on the left and the other on the right side of a computer screen. To precisely trace the allocation of focal attention, we determined the PCN. Increased negativity above visual brain areas contralateral to the relevant visual stimulus (here, the relevant wine labeling) was expressed by detecting potential changes in the PCN (Jolicoeur et al., 2008; Vossel et al., 2014). The presence of a PCN for a specific labeling points to an attentional preference for this labeling, and the more negative the PCN, the more we assumed this labeling seems to be preferred. The amplitudes of the PCN were assessed within 40-ms time windows from 0 ms to 280 ms poststimulus at the components' most typical electrode sites PO7/8, by determining lateralized potentials. Here is an example of the procedure of computing the PCN for Label 1: {[PO8-PO7 (Label 1 left visual field (LVF) - Label 2/3/4 right visual field (RVF)] + [PO7-PO8 (Label 2/3/4 LVF - Label 1 RVF)]}/2. Thus, the PCN for each label was computed by comparing it with all other labels on the ipsilateral side.

This procedure was used for all labels and for each session separately. We applied the same procedure for all symmetrical electrode sites (e.g., C3 and C4) to be able to create topographical maps displaying event-related lateralizations (ERLs; e.g., see Van der Lubbe et al., 2001). According to Töllner et al. (2011) and Töllner et al. (2012) the PCN is present from 175 to 300 ms after stimulus onset. In our case, we decided to export the data from 0 to 280 ms in seven time windows of 40 ms each. PCN values for all time windows were used for the statistical analysis. These data were analyzed with SPSS (IBM SPSS V25.0).

For the behavioral data, participant's preferences for wine labeling and reaction time (RT) were recorded during the experiment. The participant could select their preferred wine labeling by using the left or right Ctrl key of the keyboard (depending on where the preferred label would appear). Thus, labeling preferences were determined based on the total number of trials in which they selected a specific wine. The reaction times were not analyzed as there was no real-time limit to choose the preferred wine.

Reaction time indicates the time a participant takes to respond to a task (Ramsøy, 2014). Reaction times measure individuals spontaneous or "gut instinct" responses to a stimulus (Calvert et al., 2019). In this study, we measured the amount of time it took to participants to select the desired wine labeling. RT was also determined based on the total amount of trials in which they selected a specific label.

A repeated measures ANOVA was used to analyze both the EEG, the consumer preferences and reaction time. For the behavioral data, the repeated measures ANOVA was used to analyze differences in the participants' responses to each wine labeling (*Labeling Preferences*). As mentioned before, this was determined based on the number of times a label would be selected during each session. Participants' responses were analyzed with the factors Labeling (*CE, IE, CC, and IC*), Session (*Session 1 or Session 2*), and Side (left or right). Then, differences in electrophysiological measures (changes in PCN values) were analyzed for the four bottles/labels, the sessions, and the different time windows (*40 ms each*). For the analysis, seven different time windows (from 0 to 280 ms) were selected. For both EEG and behavioral data, associated Degrees of freedom, *F*-values, *value of p*s, Means, and Std. Deviation were reported. The associated Mauchly's test of sphericity was also analyzed. Corrected results (Greenhouse–Geisser or Huynh-Feldt correction)[4] were reported when the assumption of sphericity was violated.

RESULTS

Behavioral Data

The results show that there was no significant effect of Side of stimulus presentation [$F_{(1,24)} = 0.14$; $p = 0.707$] and Session [$F_{(1,24)} = 2.39$; $p = 0.136$] on participants preferences for specific wine bottles/labels. Thus, participants' preferences were not affected by the session and the presentation side of the bottle/label. However, results show that there was an effect of Labeling on participants' responses [$F_{(3,22)} = 12.29$; $p < 0.001$].

Separate comparisons between the different wine labeling were performed to determine the participants' preferences. There was a preference for the Chilean Expensive (CE) as compared to the other wine labeling (see **Figure 3**). Specifically, there was a significant difference in the number of times that the CE was selected as compared to the Italian expensive (IE) [$t_{(24)} = 7.560$; $p < 0.0001$], Chilean cheap (CC) [$t_{(24)} = 9.642$; $p < 0.0001$] and Italian cheap (IC) wine [$t_{(24)} = 10.268$; $p < 0.0001$]. Similarly, there was a strong effect of IE on participant's preferences compared to CC [$t_{(24)} = 3.333$; $p < 0.001$]. A slight difference was observed IE compared to IC [$t_{(24)} = 2.533$; $p = 0.013$]. However, no significant differences were found between CC and IC [$t_{(24)} = -1.057$; $p = 0.293$]. As shown in **Figure 3**, the most preferred wine labeling was CE, followed by IE, IC and CC.

A repeated measures ANOVA was also conducted on RT. The results show that there was no significant effect of session [$F_{(1,24)} = 0.38$; $p = 0.53$] on participants' reaction times for specific wine labeling. Thus, participants' reaction times were not affected by the session. However, the main effect of the labeling was slightly significant [$F_{(3,22)} = 5.85$; $p = 0.008$]. This means that there was a difference in the response time of participants for the wine labeling. Overall, participants were more likely to make quicker decision if they were selecting the preferred bottle/label. As shown in **Table 1**, reaction times for CE were faster than for the other labeling (IE, CC, and IC). Participants took more time to select the least preferred labeling (CC).

EEG Data

To verify whether there were changes in the PCN amplitudes as a function of Labeling (*CE, IE, CC, and IC*), Time window (7), and Session (2), a repeated measures ANOVA was performed.

The results revealed no differences in the PCN amplitudes between the two sessions [$F_{(1,24)} = 1.27$; $p = 0.271$] and also no effect of Time Window [$F_{(3.128,75.072)} = 1.47$; $p = 0.230$], but a major effect of Labeling ($F_{(2.039,48.943)} = 11.11$; $p < 0.0001$). An interaction was additionally observed between Time Window and Labeling [$F_{(5.887,141,296)} = 13.5$; $p < 0.0001$], but not between Time Window, Labeling, and Session [$F_{(8.33,199.91)} = 1.4$; $p = 0.204$]. The results suggest that there was a change in participants' brain activity over time that differed between the wine labeling (*IE, CE, IC, and CC*). These changes over time are also clearly visible in **Figure 4**.

In order to analyze changes in participants' brain activity over time as a function of Labeling, separate analyses were performed for the seven time windows. As this implies testing ten separate contrasts for each time window, we employed a critical value of p of 0.005 (i.e., we applied Bonferroni correction). For both the first (0 to 40 ms) and second (40 to 80 ms) time windows, results show no effects of Labeling ($p > 0.394$) on PCN amplitudes.

[4]The Greenhouse–Geisser correction was used for $\varepsilon < 0.75$, and the Huynh-Feldt correction was used for $\varepsilon > 0.75$.

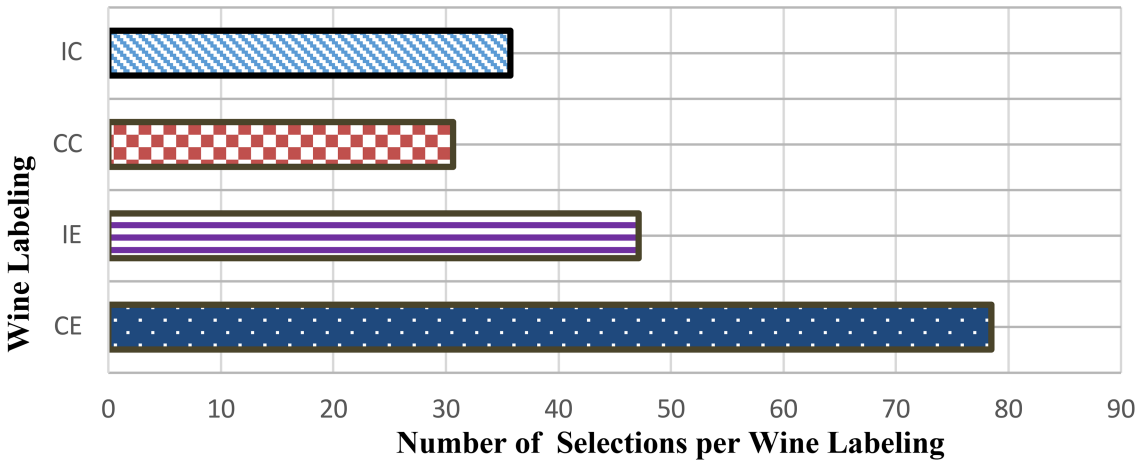

FIGURE 3 | The figure shows the participants' preferences for wine labeling (number of times the participants selected the wines).

TABLE 1 | Mean of the participants' reaction times for each example of wine labeling, and standard error of the mean.

Label	Mean	Std. Error
CE	762.402	41.275
IE	860.673	47.112
CC	956.514	68.976
IC	886.368	43.461

In the third time window (80 to 120 ms), an effect of Labeling was observed [$F_{(3,72)} = 8.7$; $p < 0.0001$]. **Table 2** shows the mean of the PCN amplitudes for the four labels in the two sessions. Contrast analyses for the third time window revealed major differences between the CE and the IC wine [$F_{(1,24)} = 17.7$; $p < 0.0004$]. The critical value of p was not crossed for the other contrasts. The mean amplitudes in **Table 2** show a clear PCN for the IC wine, while an opposite effect is present for the CE wine, suggesting that within this time window participants attend to the IC and not to the CE label.

In the fourth time window (from 120 ms to 160 ms), a main effect of Labeling on PCN amplitude was observed [$F_{(1.982,47.560)} = 21.194$; $p < 0.000001$]. Contrast analyses revealed major differences between the IC wine as compared to the CE, IE, and CC wine [$F_{(1,24)} > 24.354$; $p < 0.0001$]. Inspection of the mean amplitudes in **Table 4** again shows a clear PCN for the IC wine, while opposite effects seem present for the CE and IE labeling, suggesting that participants paid attention to the IC wine and did not attend to the CE and IE wines.

In the sixth time window (from 200 to 240 ms), again a main effect of Labeling on PCN amplitudes was found [$F_{(3,75)} = 14.4$; $p < 0.000001$]. In this case, contrast analyses revealed no differences between the CE and IC label [$F_{(1,24)} = 0.696$; $p = 0.413$], but differences were observed between the CC and IC label ($F_{(1,24)} = 25.043$; $p < 0.0001$) and between the CC and CE label [$F_{(1,24)} = 26.993$; $p < 0.0001$]. The mean amplitudes for this time window for each wine are presented in **Table 5**. It seems that now participants were paying attention to both the CE and IC wines, while they were clearly not paying attention to the CC wine.

In the seventh time window (from 240 to 280 ms), a main effect of Labeling on PCN amplitude was observed [$F_{(2.391,57.394)} = 5.948$; $p = 0.002737$]. Contrast analyses revealed differences between the CE label and the IE and CC labels [$F_{(1,24)} > 10.729$; $p < 0.0032$], but for the other contrasts, the critical value of p was not crossed. Inspection of the mean amplitudes for this time window (**Table 6**) suggests that the participants were no longer paying attention the IC wine, but attended to the CE wine.

DISCUSSION

Investigating consumer behavior with products helps companies to understand how consumers select a product and what role external characteristics (e.g., label and price) play an important role in product differentiation. In marketing research, a lot of attention has been devoted to study consumer preferences for product external characteristics (Olson and Jacoby, 1972; Inscha and McBride, 2004; Aaker et al., 2011; Armstrong et al., 2014). Despite decades of scientific effort, much is still unknown about the effects of product external characteristics on consumer decisions and preferences.

Consumer neuroscience studies show that our preferences for a product may already be reflected in our brain activity long before we make a final decision (Plassmann et al., 2012; Ma et al., 2019a,b; Sung et al., 2019; Alvino et al., 2020; Ciceri et al., 2020; Fan et al., 2020; Yu et al., 2020). The use of neuroscientific tools to study consumer behavior could improve our understanding of how external characteristics influence consumers' preferences for a product (Plassmann et al., 2012; Alvino et al., 2020). In particular, consumer neuroscience tools can be used to examine the psychological and neural mechanisms

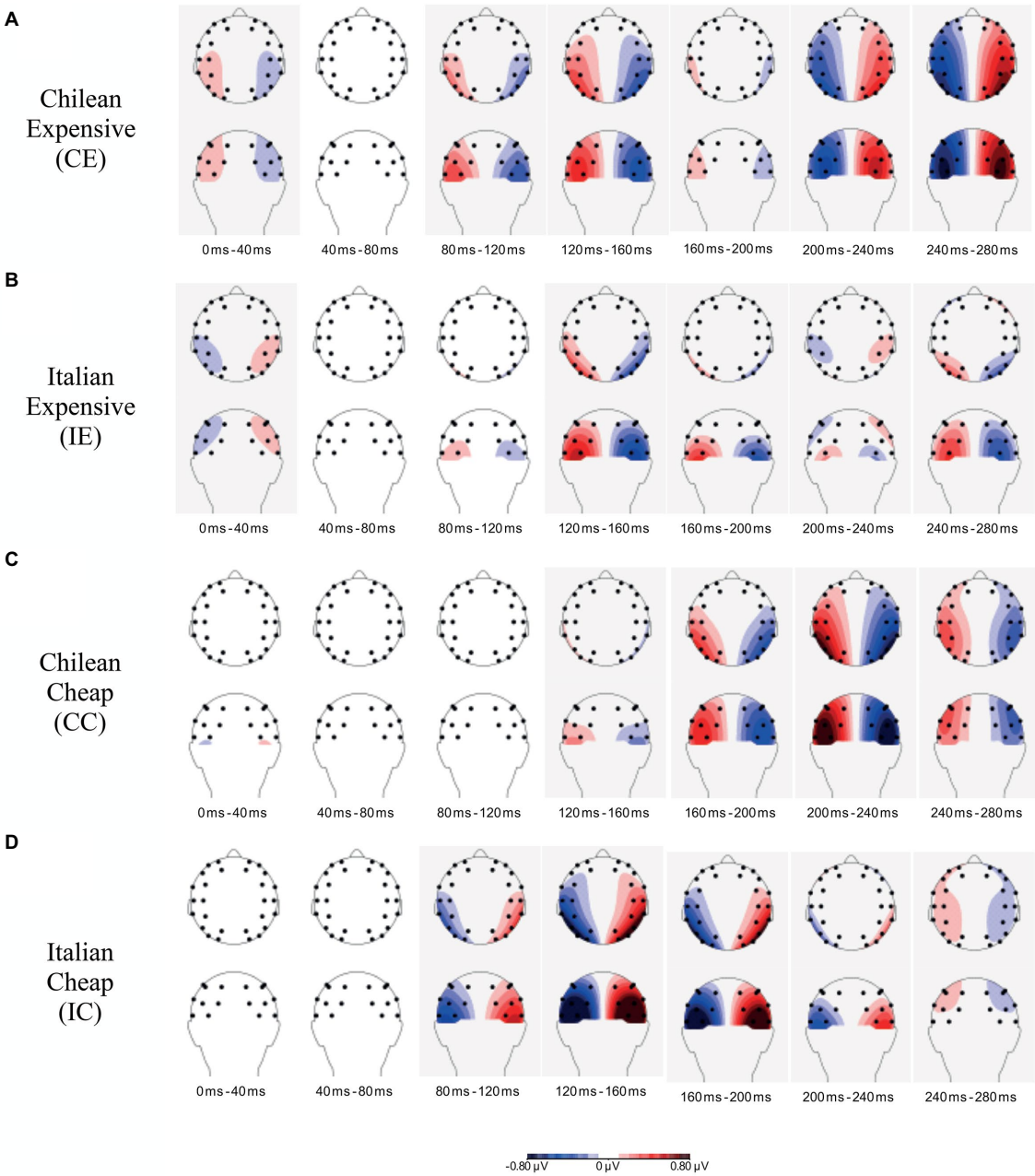

FIGURE 4 | Topographical maps determined for 40-ms time windows (from 0 until 280 ms) after stimuli presentation for all four wines: Chilean Expensive **(A)**, Italian Expensive **(B)**, hilean Cheap **(C)** and Italian Cheap **(D)**. Contra-ipsilateral differences relative to the label of interest are projected on the left hemisphere, while ipsi-contralateral differences are projected on the right hemisphere.

that underlie visual attention (Russo, 2015; van Loo et al., 2015; Laeng et al., 2016; Khachatryan et al., 2017; Russo et al., 2020).

The aim of this study was to investigate whether preferences for specific wine labeling are also reflected in brain measures derived from the EEG. Here, we specifically focused on the amplitude of the PCN with the idea that the labeling that eventually is mostly preferred will also induce a larger PCN than the other labels. The PCN (approx. 175 to 300 ms after stimulus implementation) can provide information about the role of visual attentional selection for the final decision. For instance, the presence of a PCN may imply that a participant is already attracted by the preferred label even before selecting it, or vice versa a label might initially attract attention (due to certain characteristics) but not be the preferred/selected label. Similarly, a label does not directly attract attention but may in the end be the most preferred label, suggesting that additional aspects apart from attention-attracting features play an important role.

TABLE 2 | Mean of the PCN amplitudes for each bottle/label averaged across sessions from 80–120 ms, standard errors of the mean, and results of *F* tests as deviation from "0."

Wine Label	Mean	Std. Error	*F*	*P*
CE	0.347	0.104	11.2	0.003*
IE	0.168	0.081	4.3	0.05
CC	−0.033	0.094	0.1	0.725
IC	−0.478	0.132	13.1	0.001*

**This value of p can be considered significant as it is below the critical value of 0.005.*

TABLE 3 | Mean of the PCN amplitudes for each bottle/label averaged across sessions from 120 to 160 ms, standard errors of the mean, and results of *F* tests as deviation from "0."

Wine Label	Mean	Std. Error	*F*	*P*
CE	0.435	0.118	13.7	0.001*
IE	0.578	0.162	12.8	0.002*
CC	0.210	0.152	1.9	0.181
IC	−1.199	0.177	45.7	< 0.0001*

**This value of p can be considered significant as it is below the critical value of 0.005.*

TABLE 4 | Mean of the PCN amplitudes for each bottle/label averaged across sessions from 160 to 200 ms, standard errors of the mean, and results of *F* tests as deviation from "0."

Wine Label	Mean	Std. Error	*F*	*P*
CE	0.076	0.091	0.7	0.41
IE	0.421	0.130	10.5	0.003*
CC	0.501	0.094	28.3	< 0.0001*
IC	−0.984	0.132	55.2	< 0.0001*

**This value of p can be considered significant as it is below the critical value of 0.005.*

The findings of our study (electrophysiological data) show that different label characteristics have an influence on brain activity. The results clearly reveal that the amplitude of the PCN differed between the employed wine labeling. The data suggest the presence of a PCN for two of the presented labels (CE and IC), while opposite effects seem present for the IE and CC labels, suggesting reduced attention for these labels. These changes are also visible over time. The earliest sign of the PCN was present for the IC label within the 80- to 120-ms time window, which remained until the 200- to 240-ms time window. A relevant observation of this early PCN is that it remains more or less restricted to posterior brain areas, suggesting that it reflects attentional selection and not hand motor activation, which can be observed above central areas (i.e., as measured at the C3 and C4 electrode locations). In fact, the behavioral data indicate that the IC label is only the third preferred label. A possible explanation is that the IC label had a salient and visually appealing aspects embodied in the label (contemporary fonts and abstract forms) and the bottle had a peculiar shape, different from the other wines (e.g., elongated neck; Elliot and Barth, 2012). Our interpretation of these results is that the bottle shape may have attracted participants' attention, but in the end did not lead to a preference for this label. For the CE label, the earliest sign of the PCN is within the 200- to 240-ms time window, which further increased in the 240- to 280-ms time window. Importantly, in this case the topography of the PCN seemed to spread more to hand motor areas, suggesting not only that this label was paid attention, but also preferred as it may have led to hand motor activation. This might mean that the observed lateralization is actually a combination of the PCN with the lateralized readiness potential (LRP, e.g., see Van der Lubbe et al., 2001). As the behavioral data also point out in the same direction (both preferences and RT), our assumption is that participants indeed seemed to prefer the CE label.

The behavioral data show participants' preferences for the four labels. Participants favored the labels of the more expensive wines (CE and IE) as compared to the cheap wines (CC and IC). The labels of the expensive wines had two different designs. The label of the CE wine had a traditional label, while the IE had a rather modern label. Interestingly, participants were not aware of the difference in price range among the wines; thus, price did not influence their preferences. Similarly, the style of the label (modern vs. traditional) did not play a role. However, both labels clearly showed the production year, the name of the wine, and producer, and they had bronze and golden patters. Thus, participants may have preferred these labels due to the color and information provided on the labels (CE and IE), which may have increased the overall aesthetic appeal of the wine label. Our results suggest that different elements of the wine label may have influenced the perceived value and quality of the product. This confirms discussion in the literature that labels should offer reassurance that the wine offers value for money in terms of quality (Thomas and Pickering, 2003; Barber et al., 2006). Similar to the CE, the label of the IC wine displayed the type of grape variety (Cabernet Sauvignon), name of the wine, and the producer. As well as this, the IC wine had similar colors to the IE wine (red and goals). Consumer often gravitate toward brightly colored labels, such as gold, and other elements of the wine such as its appellation, country of origin, and year of production (Johnson and Bruwer, 2007; Hall and Mitchell, 2008; Terrien and Steichen, 2008; Atkin and Johnson, 2010; Famularo et al., 2010; Elliot and Barth, 2012; Larson, 2012). It is possible that some aspect of the IC label might have affected participant's attention when they were initially exposed to the label. However, when participants had to make a conscious choice about the IC wine, they did not find the label aesthetical appealing. Consumers make a choice also based on what impression the label makes, in terms of content's authenticity and quality. Thus, a comparison of the IC and CC labels with more expensive wines might have influenced participants' preferences for it. This suggests that participants' perceived quality for the IC label was less than for expensive wines (CE and IE).

The analysis of reaction times, recorded when participants classified the wine label, also confirms these findings. Research shows that the more we like something, the faster we tend to respond (Ramsøy, 2014; Calvert et al., 2019; Kim et al., 2020). Our results reveal that participants had shorter RT for the most preferred label CE. Vice versa, the CC label had the

TABLE 5 | Mean of the PCN amplitudes for each bottle/label averaged across sessions from 200 to 240 ms, standard errors of the mean, and results of F tests as deviation from "0."

Wine Label	Mean	Std. Error	F	P
CE	−0.621	0.171	13.3	0.001*
IE	0.230	0.126	3.3	0.081
CC	0.808	0.135	35.8	< 0.0001*
IC	−0.413	0.155	7.1	0.014

**This value of p can be considered significant as it is below the critical value of 0.005.*

TABLE 6 | Mean of the PCN amplitudes for each bottle/label averaged across sessions from 240 to 280 ms, standard errors of the mean, and results of F tests as deviation from "0."

Wine Label	Mean	Std. Error	F	P
CE	−0.798	0.243	10.8	0.003*
IE	0.459	0.197	5.5	0.028
CC	0.264	0.126	4.4	0.047
IC	0.072	0.204	0.1	0.726

**This value of p can be considered significant as it is below the critical value of 0.005.*

longest reaction time. Thus, the RT measure for CC is significantly higher than for the other three wines, confirming that this was the least preferred wine. It is interesting to notice that there was a slightly shorter mean response latency for the IE label compared to IC. On average, participants took the same amount of time to select IE and IC. Consumer neuroscience research shows that the closer in values two options are, the harder would be for a person to decide between them (Ramsøy, 2014; Kim et al., 2020). This might suggest that participants did not have a strong preference for one of the two labels, like for the CE label. Another possible explanation is that the characteristics of the IC label (design and bottle shape) might have influenced participant's attention when they were initially exposed to the label. This is also confirmed by the consumer preferences and EEG data.

Several studies indicated that consumers' preferences for a product are strongly influenced by visual attention (Glimcher and Fehr, 2013; Karmarkar and Plassmann, 2019). Consumers tend to choose the items that they look at initially or look at for the longest duration (Reutskaja et al., 2011; Laeng et al., 2016). We investigated whether the presence of the PCN could be associated with participant' preference for a specific wine labeling. EEG data clearly show that the amplitude of the PCN differed between the employed wine labeling. The PCN clearly differed between the wine labeling from 80 to 240 ms after stimulus presentation. In particular, the data suggest the presence of a PCN for two of the presented labels (CE and IC). The PCN was present for the CE and IC labels, which partially confirms the pattern present in a separate analysis of the behavioral data, as the most preferred label was CE.

Based on our interpretation, the findings suggest that the allocation of visual attention (reflected in the PCN) toward a product might reflect a preference for it but our results also show that this allocation may occur as specific features attract attention. Thus, the PCN component could be used in consumer neuroscience research to study how consumers' visual attention mechanisms and linked to preferences. Overall, the findings of our study suggest that the final choice of a consumer and consequently their preference for a product could be influenced by both visual attention mechanisms and more complex cognitive processes where the outcome may be reflected in the activation of hand motor areas.[5]

CONCLUSION

This study aims to bridge gaps in the consumer neuroscience literature on external product characteristics and in particular the effect of labels in product choice.

We contribute to previous research by studying the allocation of visual attention for product external characteristics. Several consumer neuroscience studies use eye tracking to examine visual attention mechanisms for wine labels. In our research, we used EEG to study whether different label design can influence both consumer preferences and brain activity.

By combining behavioral and EEG data, this study provides a more nuanced understanding of how neural activity related to visual attention can influence consumer information processing and decision-making. In addition, EEG research often focuses on brain waves or ERP components to investigate the attention-allocation behavior of consumer during product evaluation. To our knowledge, this is the first consumer neuroscience study that uses PCN components to assess visual attention mechanisms for wine labels.

We believe this study also has potential implications for companies and marketing practitioners. In particular, this study may serve as a reference for wine producers. The creative process behind designing a label for a particular wine has become increasingly complex and expensive, as wine companies are more frequently helped by professional designers specialized for the wine market. The findings of this study also suggest that increased attention for a product often but not always reflects a preference for it. Studying visual attention mechanisms helps companies to determine when (1) individual preference for a product is directly related to its visual saliency or is modulated by more high-level information and (2) product can catch consumers' attention as well as influence their preferences, thus whether the consumer is attracted to the product, but he/she is also willing to buy it.

To conclude, the use of Consumer Neuroscience tools, such as EEG, can help to shed light on the cognitive and neuronal mechanisms that play a role during the exposure to product external characteristics. This might help companies to improve visual saliency tests by identifying whether specific product external characteristics have a strong impact on individual preferences.

[5]We verified whether individual differences in PCN amplitude for the CE label within the 200–240 and the 240–280 ms time intervals are predictive for individual preferences. Results revealed negative correlations for both time intervals (200–240 ms; $r = -0.48$, $p = 0.007$; 240–280 ms; $r = -0.59$, $p = 0.001$). These findings indicate that the more negative the individual PCN amplitude is for a specific label, the more likely it is that this participant will select this label.

Limitations and Future Work

This study comes with some limitations that could be addressed in future research. In this study, we selected only four wine labels of the same type of grape to analyze consumers' visual attention mechanisms and preferences. For future work, we suggest researchers use different types of wine (e.g., different grape variety). This will help recreate a real-life scenario in which participants choose from different wine types. As well as this, a higher number of labels might provide a more accurate analysis of which label characteristics influence consumers' preferences (Ballester et al., 2005). We also believe that the experiment could be carried out using the method called A/B testing, whereby one half of the respondents (A) is shown the original version of the label and the second half (B) the modified label. This will help improve our understanding of how studying visual mechanisms can help companies improve their advertisement effectiveness, especially for e-commerce. This could also be applied to other type of products (e.g., detergents and clothing). Finally, designing an experiment well is important to improve the quality of Consumer Neuroscience research (Fink et al., 2007; Murray and Antonakis, 2019). In this study, our goal was to investigate whether changes in the brain activity and individual preferences for wine labels are related to the allocation of visual attention using PCN; hence, we consider this an exploratory study. We would like to invite researchers to replicate this study by further developing different aspects of the experiment procedures (e.g., using a prestudy to select the wine labels) or to collect data from different consumer neuroscience tools (simultaneously) to further improve our understanding of consumer preferences and visual attention mechanisms.

SUMMARY

We summarize the findings of our study as follows:

- The consumer neuroscience literature suggests that physiological and neurophysiological tools have been used to study whether visual attention mechanisms influence consumers' preferences.
- The consumer neuroscience literature suggests that EEG has been used to investigate the influence of external product characteristics on participants' preferences and brain activity.
- The current study shows that EEG provides relevant information about the allocation of visual attention.
- The current study shows that the PCN is an electrophysiological marker that can be used to examine the deployment of visuospatial attention for marketing stimuli.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethical Committee of the BMS faculty, University of Twente. The patients/participants provided their written informed consent to participate in this studies.

AUTHOR CONTRIBUTIONS

All authors of this article had a significant contribution in its preparation. LA and RL created and designed the study and analyzed and interpreted the EEG data. LA collected the data. LA, RL, and EC reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We would like to thank the reviewers for their feedback. We believe that their suggestions have significantly increased the quality of our manuscript.

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frontiers | Frontiers in Psychology

TYPE Original Research
PUBLISHED 13 September 2022
DOI 10.3389/fpsyg.2022.674011

Check for updates

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 February 2021
ACCEPTED 05 July 2022
PUBLISHED 13 September 2022

CITATION
Yu X, Li Y, Zhu K, Wang W and Wen W (2022) Strong displayed passion and preparedness of broadcaster in live streaming e-commerce increases consumers' neural engagement. *Front. Psychol.* 13:674011. doi: 10.3389/fpsyg.2022.674011

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Strong displayed passion and preparedness of broadcaster in live streaming e-commerce increases consumers' neural engagement

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Live streaming shopping, the streaming of real-time videos promoting products that consumers can purchase online, has recently been a booming area of e-commerce, especially during the COVID-19 pandemic. The success of live streaming e-commerce largely relies on the extent to which the broadcaster can get consumers engaged by the live stream. Thus, it is important to discover the antecedents of consumer engagement in such a context. Drawing on consumer engagement and neuroscience literature, this study used electroencephalography inter-subject correlation (EEG-ISC) to explore how broadcasters' entrepreneurial passion during live streaming videos influenced consumers' neural engagement as they watched the live streaming videos. We used the framework of displayed passion and preparedness from the entrepreneurial passion literature to predict consumer engagement. We found significant ISC for strong displayed passion, while preparedness had partially significant effects on the first, second, and summed components of ISC. The interaction effects of these two factors on the first and summed components of ISC were partially significant. Strong displayed passion and preparedness activated the left and right prefrontal regions of the consumers' brains. These findings indicate that broadcasters' displayed passion and preparedness can influence consumer engagement in live streaming e-commerce settings. Our findings suggest that a scientific approach could be used to improve a broadcaster's performance by testing ISC during rehearsals before live streaming.

KEYWORDS

live streaming, e-commerce, entrepreneurial passion, consumer engagement, inter-subject correlation, ISC, EEG

Introduction

Streaming media technology has become popular in a range of industries, especially in e-commerce settings. E-commerce conducted *via* live stream is a trend that grew tremendously during the lockdown periods of the COVID-19 pandemic (PwC, 2020). According to a research report from KPMG (2020), the overall market size of live

streaming e-commerce in China reached 433.8 billion RMB in 2019, with a 210% year-on-year growth and a penetration rate of 4.1%. Live streaming e-commerce has also opened up a market for business-to-business (B2B) e-commerce (Yu et al., 2022b). For example, a technology company used an artificial broadcaster to sell a plane in a live stream. Live stream empowers the e-commerce industry to open up a new era of online shopping.

Broadcasters are the core agents of live streaming shopping influencing consumers' internal cognitive processes such as evaluations of the trustworthiness of products (Wongkitrungrueng and Assarut, 2020). Broadcasters demonstrate the functions of products, give extremely detailed introductions to the products, answer specific questions in real-time, and organize interactive activities to entertain and attract potential consumers to "follow them" or buy products. Consumers who are cognitively engaged by live streaming shopping tend to be actively involved in real-time by watching for entertainment purposes, purchasing products, "following" the broadcasters, pressing the "like" button, and posting comments. Such interactions help the broadcaster's visibility and influence because the platform detects that many consumers are showing interest, which leads to the broadcaster being recommended to more consumers. With deep consumer engagement, broadcasters can build a strong and loyal customer base and thus improve their performance (Itani et al., 2019). Understanding how to motivate consumers to become actively engaged in a live stream is therefore important for broadcasters (Sashi, 2012; Brodie et al., 2013; Baldus et al., 2015; Kumar and Pansari, 2016; Zhang et al., 2020).

Many consumer engagement studies have considered online shopping *via* webpages (e.g., Ashraf et al., 2016), but the antecedents of consumer engagement in live streaming shopping have seldom been considered. A broadcaster's entrepreneurial passion may be a significant antecedent of consumer engagement. Entrepreneurial passion is an intense affective state accompanied by cognitive and behavioral manifestations of high personal value in entrepreneurial activities (Chen et al., 2009). Broadcasters must decide what kind of product they are going to introduce on their channel. Like entrepreneurs, they need to capture their audience's preferences precisely (Yu and Wang, 2021; Young et al., 2022). Passionate broadcasters pay attention to how to exploit opportunities (Yu et al., 2020). After deciding what products to sell, they must also prepare by deciding how they will introduce the products to consumers, including information about the product function, designing purposes, materials attribution, and so on. In addition to undertaking such preparation, passionate broadcasters often express their passion for the product during the live stream, which can attract more consumers to join the stream and stay watching (Chen et al., 2009). Thus, how entrepreneurial passion influences consumer engagement is worthy of exploration (Bowden, 2009; Ahn and Back, 2018).

In this study, we aimed to determine the effects of a broadcaster's entrepreneurial passion on the engagement of consumers watching live streaming videos by investigating the viewers' cognitive processes. To capture real-time consumer engagement and cognitive processes, we used electroencephalography inter-subject correlation analysis (EEG-ISC) and screened real live streaming shopping videos from the largest e-commerce platform in China, Taobao.com. As a report from a reliable monitoring platform (www.zhigua.cn) indicated that food has become the most popular product in live streaming shopping, we used live streaming videos selling food as our stimulus. The videos were rated on two dimensions of entrepreneurial passion—displayed passion and preparedness—by two researchers and one practitioner from a top multi-channel network (MCN) company in China and then labeled as having strong/weak displayed passion and strong/weak preparedness. The videos were then randomly assigned to participants wearing electrodes recording an EEG while they were watching. We then identified correlated components in the EEG recordings to quantify the strength of ISC across participants watching the same video. Finally, we applied analysis of variance (ANOVA) to differentiate ISC within 2 × 2 scenarios. The results revealed that for displayed passion, all of the ISC components were significantly different between the strong and weak groups. For preparedness, there was a significant difference between the groups except for the third ISC component, and the interaction of displayed passion and preparedness was significantly different between groups on the first ISC component and the summed ISC.

This study makes contributions to both theory and practice. First, our findings provide new insight into the antecedents of consumer neural engagement from a micro-foundation perspective. Second, we extend the literature on entrepreneurial passion into a new setting. Third, we apply a new method to capture consumer neural engagement at a collective level. In terms of practice, our findings could inspire broadcasters to consider entrepreneurial passion as a significant element of their performance. Our method could be used to monitor how well they perform during rehearsals. Companies could also use the method to train broadcasters and predict their performance before a formal live streaming show.

Theoretical background

Consumer engagement

Consumer engagement is an emerging research topic in the study of e-commerce (e.g., Patterson et al., 2006; Brodie et al., 2013; Vivek et al., 2014; Dessart, 2017). Consumer engagement in a virtual community involves specific interactive experiences between consumers and a brand, and/or other members of the community (Brodie et al., 2013). Such engagement is critical in

live streaming e-commerce settings for several reasons. First, consumer engagement is not only a strategic imperative for establishing and sustaining a competitive advantage but also a valuable predictor of future business performance (Zhang et al., 2020). It can be a primary driver of sales growth (Neff, 2007) and enhance profitability (Voyles, 2007). Second, real-time interaction between consumers and broadcasters gives consumers a feeling of social presence (Gefen and Straub, 2004; Hou et al., 2021), in which consumers and the broadcaster experience synchronous communication. This helps to build trust and decrease consumers' doubts about virtual products (Wongkitrungrueng and Assarut, 2020). Third, live streaming e-commerce allows consumers to participate in a socially interactive shopping experience beyond simple purchase behavior (Brodie et al., 2013). As the interaction between consumers and broadcasters occurs in real-time and can be seen by others, consumer engagement during live streaming can not only enhance a viewer's own shopping experience but also encourage other potential consumers to interact.

Brodie et al. (2013) pointed out that consumer engagement is a context-dependent, psychological state characterized by fluctuating intensity levels that occurs within dynamic and iterative engagement processes. It is a multidimensional concept containing cognitive, emotional, and behavioral dimensions (Park and Lee, 2008). However, studies have neglected the multi-dimensional characteristics of consumer engagement (Mollen and Wilson, 2010; Hollebeek, 2011). There is a need to expand existing self-report measures of consumer engagement and use real-time measurement in live streaming settings to describe the synchronous reactions that occur during consumer engagement (Fugate, 2007). A promising approach to examining and quantifying how live streaming influences consumer engagement is the use of EEG-ISC (Cohen and Parra, 2016; Imhof et al., 2020). EEG-ISC measures the consistency and similarity of complex and naturalistic stimuli-evoked brain responses across participants who are exposed to the same message, which yields a continuous, nonverbal measure of collective engagement that is well suited to quantifying the effects of mass media messages at the neural level (Hasson, 2004; Hasson et al., 2010; Dmochowski et al., 2012; Lahnakoski et al., 2014; Imhof et al., 2017). Thus, EEG-ISC can be used to capture consumer neural engagement in live streaming settings in terms of the extent to which a participant's brain becomes engrossed in a stimulus (Shane et al., 2020). Neural engagement could reflect the focus and attention on the stimulus (Barnett and Cerf, 2017). Meanwhile, compared with other ISC-based approaches such as fMRI-ISC, EEG-ISC has advantages in its temporal resolution, which is in the order of milliseconds. Such a high temporal resolution is promising for characterizing the reception of fast-paced audiovisual messages (Imhof et al., 2020). These characteristics enhance the scalability of the method and provide the potential to integrate cognitive neuroscientific approaches into industrial pre-testing, such as during rehearsals before live streaming. Recent EEG studies in classroom settings, the cinema, and during music consumption have illustrated this potential (Barnett and Cerf, 2017; Dikker et al., 2017; Poulsen et al., 2017; Cohen et al., 2018; Madsen et al., 2019). Research has indicated that ISC can be a proxy for participant engagement arising from attention or relevance-based factors (Dmochowski et al., 2012; Hasson et al., 2012; Cohen et al., 2017; Imhof et al., 2017), suggesting that it can serve as a successful marker of engagement in live streaming videos. Thus, this study aimed to explore how live streaming influences consumer engagement from a neural perspective.

Entrepreneurial passion

Entrepreneurial passion is an intense affective state accompanied by cognitive and behavioral manifestations of high personal value (Chen et al., 2009). As noted above, displayed passion and preparedness are two dimensions of entrepreneurial passion (Baron, 2008). Displayed passion, or appearing enthusiastic, is the affective dimension of passion (Shane et al., 2020). Preparedness, or how well prepared an individual is for a certain activity, is the cognitive dimension of entrepreneurial passion (Chen et al., 2009). Various studies have reported that entrepreneurial passion can motivate audiences to engage in certain economic activities (Smilor, 1997; Chen et al., 2009; Shane et al., 2020). For example, Shane et al. (2020) found that the passion entrepreneurs displayed during their crowdfunding pitches promoted the neural engagement and investment decisions of investors. Chen et al. (2009) found that only preparedness, but not displayed passion, increased the interest of investors in crowdfunding pitches.

Displayed passion and preparedness may also influence consumer engagement in live streaming settings. Displayed passion is often critical for convincing target audiences to invest their money and time (Chen et al., 2009). Broadcasters perform passionately, which helps them to attract consumers' attention, persuade them to make buying decisions, and create enduring and intimate relationships with them (Sashi, 2012). Thus, we hypothesize as follows:

H1: ISC has a positive relationship with displayed passion.

A well-prepared broadcast with a thoughtful plot and effective expression reveals the effort the broadcaster has invested. A well-prepared broadcaster makes the key point stand out and the content easy to understand, which attracts consumers to watch and stay on the channel. Broadcasters also prepare interactive events, such as lucky draws, which increase consumers' interest. Thus, preparedness might stimulate a high level of ISC and we hypothesize as follows:

H2: ISC has a positive relationship with preparedness.

Materials and methods

Participants

Forty-three participants (17 males; aged 18–29 years, M_{age} = 22.91, SD = 2.42) with normal hearing and normal or corrected-to-normal vision took part in the experiment. None of the participants had a history of neurological or psychological disorders and all were right-handed. All of them completed the pre-test and the whole EEG experiment. Data from one participant were excluded from the analysis because of technical failure during the EEG experiment. We assessed the participants' live streaming shopping experience using three questions. The first was whether they had a prior experience with live streaming shopping. If they answered "yes," then they were asked, "Do you prefer shopping *via* live stream? (yes or no)" and "How frequently do you shop *via* live stream? (1 = not at all, 7 = very frequently)." Sixteen of the participants had experienced live streaming shopping before the experiment and three of them indicated that they preferred live streaming shopping for e-commerce ($M_{frequency}$ = 3.13, SD = 1.54). After completing the experiment, the participants received 50 RMB or a gift of equal value as a reward. To simulate the real process of live streaming shopping, we gave each participant 500 RMB to shop with, which is much lower than the total price of all the products demonstrated in the videos. If the participant selected the most popular product, he or she received a floating payment of 30 RMB.

Stimulus material

We collected stimulus material from Taobao.com, which is the biggest e-commerce platform in China. As noted above, we only used live streaming videos selling food as our stimulus materials. We randomly chose 50 videos from 10 to 30 September 2020. We recorded the selected live streaming videos and chose the same recording software to avoid effects from differences in brightness, sound, and optical flow influencing the experimental results. All the videos included an introduction to the products (including characteristics and price) and hawking. We recorded a minimum of 2 min and a maximum of 3 min of the live stream to ensure that typical content was captured.

Next, two researchers with expertise in entrepreneurial passion and one practitioner, the manager of an MCN company in the live streaming e-commerce industry, were asked to independently rate the broadcasters' displayed passion and preparedness using a scale from Chen et al. (2009), which has been widely used to study entrepreneurial passion (e.g., Davis et al., 2017; Shane et al., 2020; Alison et al., 2022). The statements about displayed passion were as follows: "When introducing the product, the broadcaster's body language is very rich," "When introducing the product, the broadcaster's facial expression is very rich," and "When introducing the product, the broadcaster's eyes are glowing," and "When introducing the product, the broadcaster has a very high tone and intonation." The statements about preparedness were as follows: "The video content had substance," "The video was thoughtful and in-depth," "The video was coherent and logical," "The broadcaster articulated the relationship between the product and its function," and "The broadcaster cited facts to support his/her arguments."

The mean score for displayed passion was 4.35, with a standard deviation of 1.10. The mean score for preparedness was 4.58, with a standard deviation of 0.95. An inter-rater reliability assessment was conducted to confirm the level of agreement across the three different evaluators. Krippendorff's α was 0.827, which exceeded the "very good" threshold value of 0.80 (Landis and Koch, 1977). We categorized the videos that scored one deviation above the average as strong and those that scored one deviation below the average as weak, based on the three evaluators' scores. Videos that did not score in this range were deleted because it was hard to tell the difference between high passion and low passion. Seven videos were excluded through this process. Finally, 15 videos were rated as strong displayed passion and strong for preparedness, seven were rated as strong for displayed passion and weak for preparedness, seven were rated as weak for displayed passion and strong for preparedness, and 16 were rated as weak for displayed passion and weak for preparedness. T-tests for these four categories showed that there were significant differences among groups of videos in the broadcaster's displayed passion (M_{strong} = 4.75, SD = 0.41; M_{weak} = 3.88, SD = 0.35, t = −7.4438, p < 0.001) and preparedness (M_{strong} = 4.36, SD = 0.40; M_{weak} = 3.33, SD = 0.42, t = −8.2437, p < 0.001). To confirm that our categorization was valid, we also asked the participants to rate the broadcaster's displayed passion and preparedness using the same scale after watching each video. We assessed the agreement in the scores between the evaluators and the participants by comparing the average of the three evaluators' scores with the average of the participants' scores. Krippendorff's α was 0.662, which is higher than the "good" threshold value of 0.60 (Landis and Koch, 1977). The t-tests of the participants' scores for the four categories confirmed the differences in displayed passion (M_{strong} = 4.75, SD = 0.41; M_{weak} = 3.88, SD = 0.35, t = −7.4438, p = 0.0000) and preparedness (M_{strong} = 4.36, SD = 0.40; M_{weak} = 3.33, SD = 0.42, t = −8.2437, p = 0.0000) that had been indicated by the raters' scores.

Procedure

Before the experiment ($t1$), we obtained permission for our study from the Technology Ethics Committee of Shanghai University. We then posted a recruitment poster stating the experiment's purpose, location, duration, requirements,

remuneration, and contact information. Before the experiment, the participants were asked to clean their scalp with shampoo. They were also asked to sign an informed consent form confirming that they understood that the EEG procedure was safe and would be kept confidential. They were then asked to complete a pre-test questionnaire covering general demographic information (name, gender, age, education level, and handedness) and their spending behaviors (level of spend per month, live streaming shopping experience). Next, the experimenter led the participants into a professional EEG lab with sound, light, and magnetic insulation one by one. Each participant was fitted with a 64-channel electrode cap, external electrodes, and conductive paste. This usually took 20 min.

During the experiment (*t*2), each participant was randomly shown 15 of the 45 live streaming shopping videos. Each video was viewed by at least 12 participants. The videos were presented *via* E-prime 2.0 at a resolution of 1,920 × 2,080 pixels on a 24" flat screen monitor, located around 55–75 cm in front of the participant. First, the instructions for the experiment were presented on the screen for at least 30 s. When the participant pressed the space key, the next process was a familiarization exercise. In the formal round, a 3-s fixed-image was shown before each video. After a 2-min video clip, the participants had to make a purchase decision using the "Buy Now" and "Not Interested" buttons displayed on the screen to proceed to the rest of the experiment. At the end of each video, a questionnaire about the displayed passion and preparedness of the broadcaster (Chen et al., 2009) was presented on the screen and the participants were asked to score that broadcaster between one (not at all passionate) and seven (very passionate). Each experiment lasted for approximately 1.5 h, with a break of 5–10 min

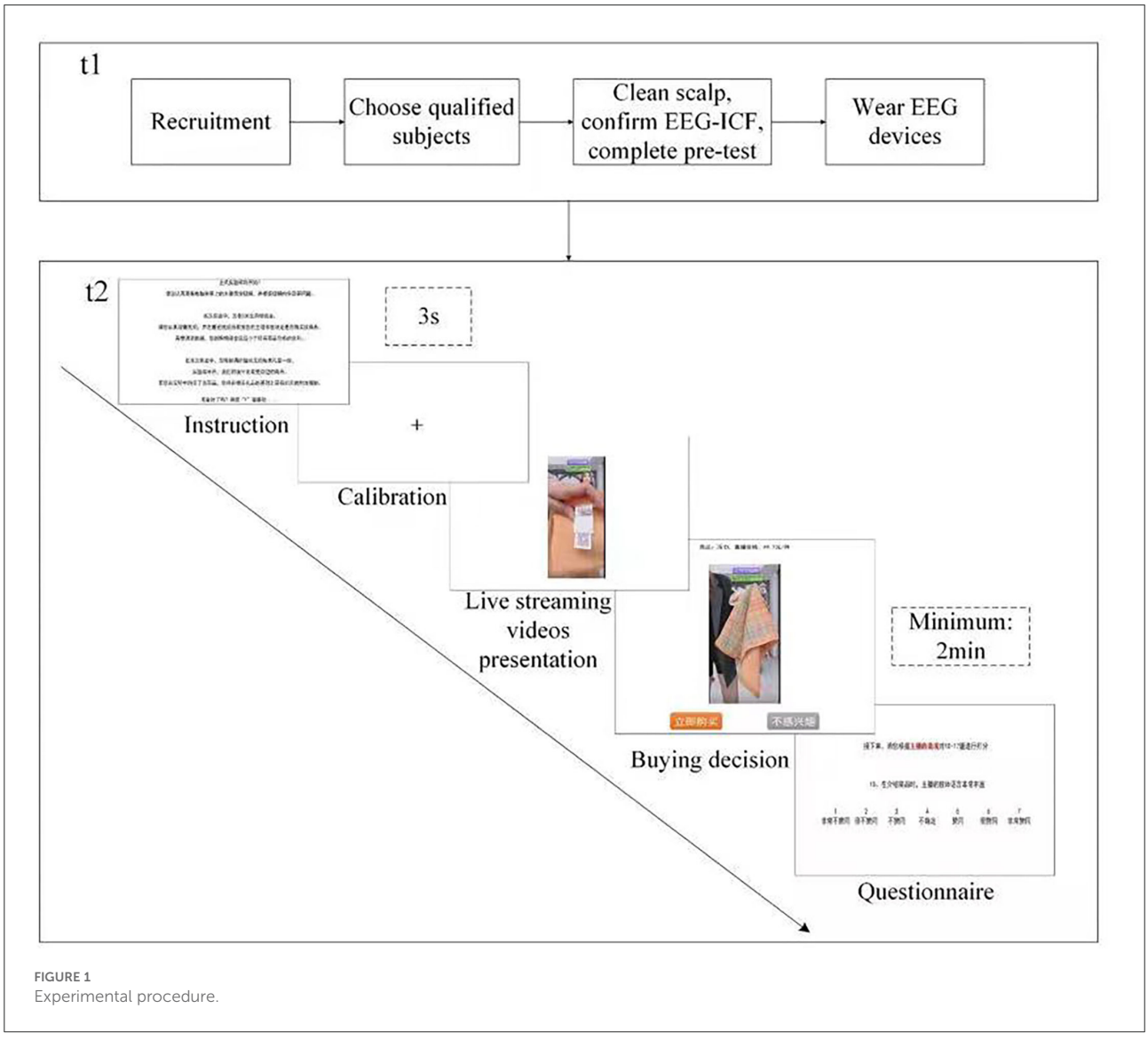


FIGURE 1
Experimental procedure.

after the eighth video. The experimental procedure is shown in Figure 1.

EEG acquisition and preprocessing

The acquisition of the EEG was made using an ActiCHamp amplifier with 64 channels developed by Brain Products. The EEG was sampled at 256 Hz and the electrodes were distributed on the participants' scalps following the international standard 10–20 system. The vertex electrode (Cz) was the reference electrode. To ensure data quality, scalp impedance must remain below 10 kΩ. All the participants' scalp impedance values were below 10 kΩ at the beginning of the experiment, and we also tried to adjust each electrode during the rest time between the two rounds. However, the scalp impedance of several participants was higher than 10 kΩ for several videos. We documented these instances and excluded eight EEG records from the ISC analysis. We ensured each video had at least 12 observations, which was necessary for calculating EEG-ISC according to prior research (Cohen and Parra, 2016).

We preprocessed the raw data following the procedures of prior studies (Dmochowski et al., 2012, 2014; Cohen and Parra, 2016; Cohen et al., 2017; Imhof et al., 2020). The preprocessing was done using BrainVision Analyzer software (Brain Products, 2013). Specifically, EEG data were set at 0.5 Hz for high pass and 50 Hz for notch filter. As participants tend to blink during experiments, which can affect the prefrontal region, it is necessary to eliminate the effect of blinking on the results by removing the interference signals. We removed eyeblinks using the ICA-based ocular artifact rejection function of the BrainVision Analyzer software. We manually confirmed the ocular components after the system selected the eligible components by ICA. As we had marked the live streaming videos using the E-prime program, we then segmented the EEG data according to the marks. Finally, we put the segmented EEG data into Matlab to identify the outlier samples in each specific channel. Outlier samples were those values that were four times larger than the distance between 25 and 75%, and we used zero values to replace 40 ms before and after the outliers (Cohen and Parra, 2016).

EEG-ISC analysis

We used the open-source code for EEG-ISC developed by Parra and other scholars (available at http://www.parralab.org/isc/). EEG-ISC calculates the maximally correlated components by capturing a linear combination of electrodes that are consistent across participants and maximally correlated between them (Cohen and Parra, 2016). Compared with fMRI-ISC, EEG-ISC can detect temporal-scale response patterns to stimuli (Dmochowski et al., 2012; Cohen and Parra, 2016; Imhof et al., 2020). We used within- and between-subject covariance matrices that were averaged across all videos to calculate the correlated components. We further extracted three components to capture most of the ISC, and the corresponding correlation values were computed separately for each component and each video. We also calculated the sum of the three largest correlated components to enable comparison with previous research (Cohen and Parra, 2016). As components are temporally uncorrelated with other components and capture different sources of neural activity, we used the "forward model," which represents the covariance between the activity of each component and the activity of each electrode location (Parra et al., 2005) to visualize the spatial distribution of different sources (Parra et al., 2005).

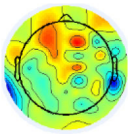
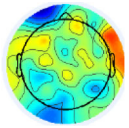
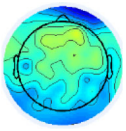
Statistical analysis

We performed three major analyses. First, we used the Kolmogorov–Smirnov test and Levene's test to check whether our data satisfied the assumptions of normality and uniformity of variance required for ANOVA. Second, we applied ANOVA to test the statistical differences among different categories. Third, we applied the least significant difference (LSD) *post-hoc* analysis to provide a robust test of the differences' direction and magnitude. All analyses were performed using SPSS 20.0 for Windows.

Results

The purpose of this study is to investigate the influence of broadcaster's displayed passion (2 levels, strong and weak) and preparedness (2 levels, strong and weak) in live streaming on consumer's neural engagement. For each component, the effect of displayed passion and preparedness was assessed *via* ANOVA. In order to examine the degree of neural engagement within participants, we measured 43 participants' EEG activity during video presentation to assess neural processing. To calculate ISC, we extracted the three most correlated components and summed the ISC of the EEG data (Cohen and Parra, 2016). We expected that strong displayed passion, strong preparedness, and the interaction between them would be associated with higher ISC than weak displayed passion and poor preparedness. As shown in Figure 3, the LSD *post-hoc* analysis revealed that for component 1 and the summed components, the weak displayed passion*strong preparedness condition was associated with significantly higher ISC than the weak displayed passion*weak preparedness condition (C_1: $p = 0.003$; C_{sum}: $p = 0.001$), strong displayed passion*weak preparedness condition (C_1: $p = 0.015$; C_{sum}: $p = 0.000$), and strong displayed passion*strong preparedness condition (C_1: $p = 0.001$; C_{sum}: $p = 0.000$).

TABLE 1 Results of two-way ANOVA comparing brain coupling during different dimensions.

	Effect	*F*	*p*-value	Sum of Squares	η^2
Component 1	Displayed passion	6.42	0.0154	0.01791	0.12
	Preparedness	3.13	0.0848	0.00872	0.06
	Displayed passion × Preparedness	7.19	0.0107	0.02006	0.14
Component 2	Displayed passion	6.82	0.0127	0.01330	0.15
	Preparedness	3.53	0.0678	0.00688	0.08
	Displayed passion × Preparedness	0.22	0.6421	0.00043	0.00
Component 3	Displayed passion	6.41	0.0155	0.00022	0.14
	Preparedness	0.48	0.4911	0.00002	0.01
	Displayed passion × Preparedness	0.36	0.5507	0.00001	0.01
Summed component	Displayed passion	17.15	0.0002	0.06973	0.27
	Preparedness	8.01	0.0073	0.03256	0.13
	Displayed passion × Preparedness	6.20	0.0172	0.02521	0.10

Pre-requisite for ANOVA

The Kolmogorov-Smirnov normality test was performed to confirm that the data were sampled from components with a normal distribution. The *p*-values of the Kolmogorov-Smirnov test were all larger than 0.05 (C_1: $p = 0.841$; C_2: $p = 0.989$; C_3: $p = 0.727$; C_{sum}: $p = 0.336$), indicating that all ISC components and summed components followed a normal distribution.

Levene's test evaluates the null hypothesis that the component variances are homogeneous. When the *p*-value is < 0.05, the null hypothesis is rejected, and it can be concluded that there is a difference between the variances of components. The results of the Levene test showed that the assumption of homogeneity of variances for the components was supported (C_1: $p = 0.637$; C_2: $p = 0.530$; C_3: $p = 0.051$; C_{sum}: $p = 0.139$). As the data were confirmed to follow a normal distribution and to have homogeneous variance, the pre-requisites for ANOVA were satisfied.

ANOVA

The results of ANOVA showed that all the ISC components while viewing live streaming videos were significantly correlated with the broadcaster's displayed passion (C_1: $F = 6.42$, $p = 0.0154$; C_2: $F = 6.82$, $p = 0.0127$; C_3: $F = 6.41$, $p = 0.0155$; C_{sum}: $F = 17.15$, $p = 0.0002$; for details, please see Table 1). The results also confirmed that preparedness was significantly correlated with C_1, C_2 and C_{sum} (C_1: $F = 3.13$, $p = 0.0848$; C_2: $F = 3.53$, $p = 0.0678$; C_3: $F = 0.48$, $p = 0.4911$; C_{sum}: $F = 8.01$, $p = 0.0073$). As shown in Figure 2, it was possible to discern differences between the effects of different video categories on all ISC components and summed ISC. These results support our hypotheses that strong passion and preparedness in live streaming videos prompt ISC among participants.

We also applied a two-way ANOVA to identify the interaction effect of the two dimensions. The results revealed that the interaction of "displayed passion* preparedness" reached significance for C_1 and C_{sum} (C_1: $F = 7.19$, $p = 0.0107$; C_{sum}: $F = 6.20$, $p = 0.0172$), but not for C_2 or C_3 (C_2: $F = 0.22$, $p = 0.6421$; C_3: $F = 0.36$, $p = 0.5507$). To clarify the direction of interaction effects, we conducted a simple effects test. The results showed that with weak displayed passion the simple effects of preparedness were significant for C_1 ($F = 8.79$, $p = 0.031$) and C_{sum} ($F = 8.84$, $p = 0.031$), but they were not significant when displayed passion was strong. With strong preparedness, the simple effects of displayed passion were significant for C_1 ($F = 12.07$, $p = 0.018$) and C_{sum} ($F = 12.91$, $p = 0.016$). A box plot of the main effects and interaction effects is shown in Figure 2.

Post-hoc analysis

We used category 1 to category 4 to represent the "weak displayed passion*weak preparedness," "weak displayed

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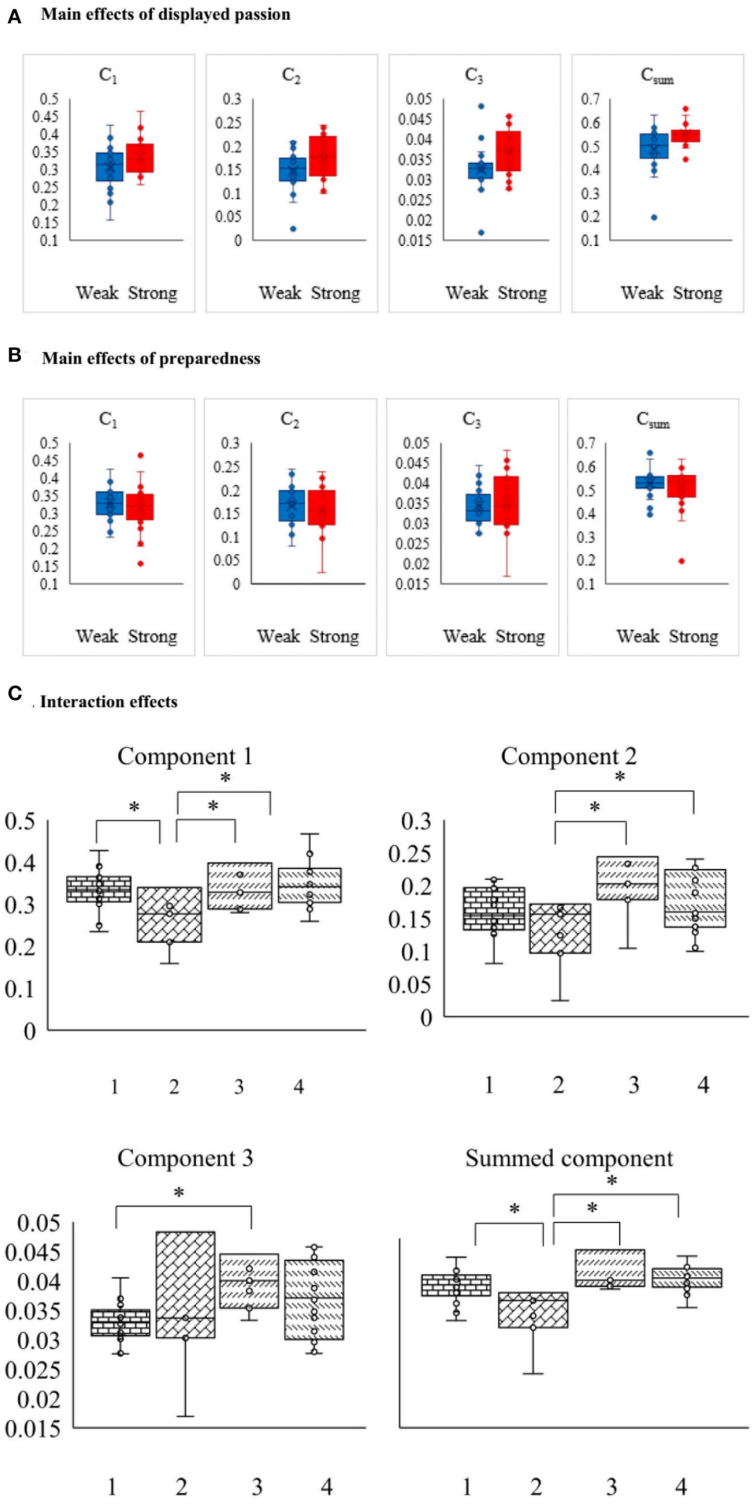

FIGURE 2
EEG-ISC detects differences during the viewing of different videos. (1) Box plots a and b show average EEG-ISC for each component, separated by video categories high (red) and low (blue) passion. We use a smaller scale unit on the third component to show differences among different videos because the third one captured least ISC among all those components. (2) Box plots c show average EEG-ISC for each component, separated by video categories (1–4). Video category 1–4 represents "weak displayed passion*weak preparedness," "weak displayed passion*strong preparedness," "strong displayed passion*weak preparedness," "strong displayed passion strong preparedness." We use a smaller scale unit on the third component to show differences among different videos because the third one captured least ISC among all those components.

TABLE 2 Results of LSD *post-hoc* analysis.

	Groups		*p*-value	Mean difference	Std. Error
Component 1	1	2	0.003	0.080*	0.025
		3	0.917	0.003	0.025
		4	0.473	−0.014	0.019
	2	3	0.015	−0.077*	0.030
		4	0.001	−0.094*	0.026
	3	4	0.524	−0.016	0.026
Component 2	1	2	0.104	0.035	0.021
		3	0.136	−0.032	0.021
		4	0.492	−0.011	0.016
	2	3	0.012	−0.067*	0.025
		4	0.036	−0.046*	0.021
	3	4	0.492	0.011	0.016
Component 3	1	2	0.947	0.000	0.003
		3	0.032	−0.006*	0.003
		4	0.090	−0.004	0.002
	2	3	0.065	−0.006	0.003
		4	0.182	−0.003	0.003
	3	4	0.367	0.003	0.003
Summed component	1	2	0.001	0.115*	0.031
		3	0.248	−0.036	0.031
		4	0.222	−0.028	0.023
	2	3	0.000	−0.151*	0.037
		4	0.000	−0.144*	0.031
	3	4	0.812	0.007	0.031

*$p < 0.05$.

passion*strong preparedness," "strong displayed passion*weak preparedness," and "strong displayed passion*strong preparedness" conditions, respectively. The results of the LSD *post-hoc* analysis are shown in Table 2.

For component 1 and the summed components, the *post-hoc* analysis showed that the ISC of category 2 was significantly higher than the ISC of the other categories ($p < 0.05$). The ISCs of categories 1, 3, and 4 were not statistically different from each other. These results suggest that for component 1 and the summed components, the "weak displayed passion*strong preparedness" condition was most effective in activating higher ISC.

For component 2, the analysis showed that the ISC of category 2 was significantly higher than that of category 3 ($p < 0.05$) and category 4 ($p < 0.05$), and the ISCs of categories 1, 3, and 4 were not statistically different from each other. Thus, we can conclude that the "weak displayed passion*strong preparedness" condition activated higher ISC than the "strong displayed passion*weak preparedness" and "strong displayed passion*strong preparedness" conditions did.

For component 3, the analysis showed that the ISC of category 3 was only significantly higher than that of category 1 ($p < 0.05$). The ISCs of categories 1, 2, and 4 were also not statistically different from each other. Thus, we can conclude that the "strong displayed passion*weak preparedness" condition activated higher ISC than the "weak displayed passion*weak preparedness" condition did.

Sensor contribution analysis

Figure 3 visualizes which sensors contributed to the correlated components and reveals distinct topographies for each component using their forward projections. The spatial distribution of the components represents the covariance between a component's activity and the activity at each sensor (Dmochowski et al., 2012; Cohen and Parra, 2016). Combining the results of the ANOVA (Table 1) and sensor contribution (Figure 2) enabled us to conduct further analysis to better understand the different sources of neural engagement in the different categories, although EEG does not reflect brain regions as precisely as fMRI does.

As shown in Table 1, the activated brain region of C_2 was the prefrontal region. It has been found that the prefrontal region mainly has functions of affective engagement and judgment (Dulabh et al., 2017). As shown in Figure 2, we found that the prefrontal region was more strongly activated by the videos with strong displayed passion than by those with weak displayed passion. This was also the case for strong and poor preparedness. Thus, the sensor contribution was in accordance with our ANOVA results. These results show that strong displayed passion motivated more neural engagement than weak displayed passion did, and the same was true for strong vs. poor preparedness.

The activated brain regions of C_2 were the left prefrontal lobe, left frontal lobe, and right frontal lobe. The left prefrontal lobe is mainly associated with enhancing the memory of stimuli (Gabrieli et al., 1998), and the left and right frontal lobes are mainly associated with motor events (Decety, 1996). The strong displayed passion and strong preparedness videos activated the left prefrontal lobe more extensively and significantly than their weak counterparts did. This brain region is responsible for enhancing the memory of stimulus, which is related to engagement in the context of live streaming shopping. Although the weak displayed passion videos and poor preparedness videos activated the left and right frontal lobes, these areas are responsible for motor events, which are irrelevant to our setting. Thus, the sensor contribution of C_2 was in accordance with the ANOVA results, indicating that strong displayed passion motivated more neural engagement than weak displayed passion did and strong preparedness motivated more neural engagement than poor preparedness did.

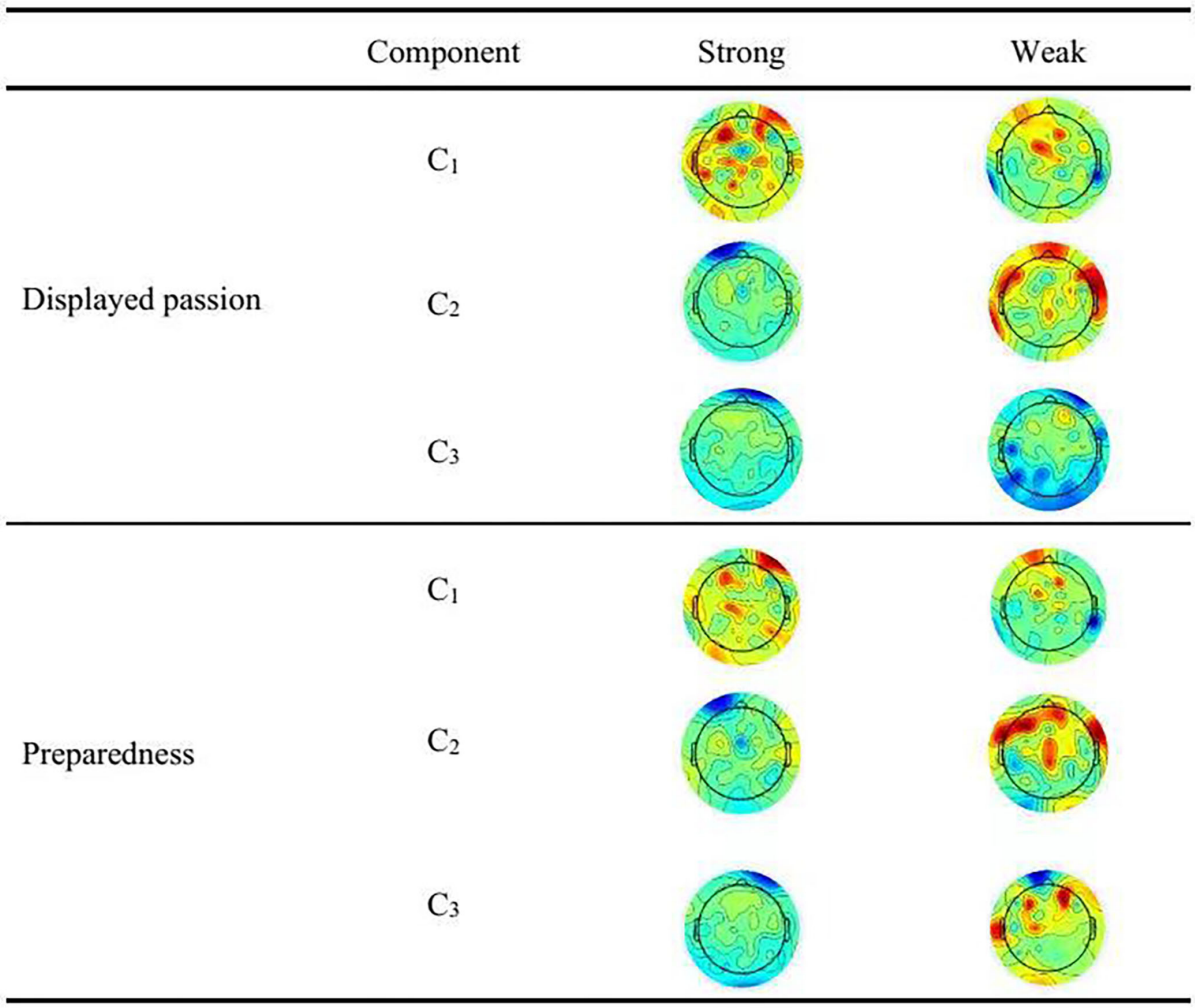

FIGURE 3
Sensor contribution. Topographical map visualizes the strength that each sensor contributes to the correlated component. Each column represents the forward model (con-elation between surface electrodes and component activity) obtained using either all stimuli together (combining responses across all participants). The maps reveal the contribution by showing interpolated magnitudes of the scalp projections, that is the forward models of the maximally correlated components C_1 to C_3.

The activated brain regions of C_3 were around the right prefrontal lobe and right frontal lobe. It has been found that the right prefrontal lobe is mainly associated with episodic memory retrieval (Buckner et al., 1996) and the right frontal lobe is mainly associated with self-awareness (Stuss, 1991). Compared with weak displayed passion, strong displayed passion activated the right prefrontal lobe extensively and significantly. This brain region is responsible for episodic memory retrieval, which is related to engagement during the live stream. Although weak displayed passion activated the right frontal lobe, this area of the brain is mainly responsible for self-awareness and is less related to engagement in the context of live streaming shopping. Therefore, the sensor contribution of C_3 was also in accordance with the ANOVA results, indicating that strong displayed passion motivated more neural engagement than weak displayed passion did.

Discussion

This study explored the antecedents of consumer neural engagement in a live streaming e-commerce setting, breaking new ground by studying the inter-subject neural activity of consumers in a live streaming shopping setting (Dulabh et al., 2017). We found significant EEG-ISC for videos characterized by strong displayed passion, while the effects of preparedness were partially significant for the first, second,

and summed components of EEG-ISC. The conjoint effects of these two factors were partially significant for the first and summed components of EEG-ISC. Strong displayed passion was found to trigger activity in the left and right prefrontal regions of the brain, indicating that broadcasters with strong displayed passion can motivate consumers to engage with live streaming shopping. Strong preparedness triggered activity in the left prefrontal region, suggesting that well-prepared broadcasters can also motivate consumers to engage with live streaming shopping. Overall, we conclude that both strong displayed passion and strong preparedness can promote consumer engagement in live streaming shopping. Overall, we found that displayed passion was the main antecedent of consumer engagement in live streaming e-commerce; preparedness only partially enhanced consumer engagement. These two characteristics jointly enhanced consumer neural engagement.

Theoretical contribution

Our results make three major contributions to the e-commerce literature, the entrepreneurial passion literature, and the neuroscience of EEG-ISC literature. First, we extend the micro-foundation of consumer engagement literature by reporting the antecedents of consumer engagement with live streaming e-commerce (Yu et al., 2022a). Consumer engagement is an extremely important performance indicator for live streaming e-commerce, but it is hard to find evidence of the factors influencing consumer engagement in this setting (Wongkitrungrueng and Assarut, 2020). This study found that consumers were more engaged if broadcasters displayed more passion. A well-prepared introduction to the products being sold also directly enhances consumer engagement.

Second, we contribute to the entrepreneurial passion literature by depicting the role of passion in a live streaming setting. Research has indicated the significant role of passion in a range of settings. Chen et al. (2009) revealed that preparedness but not displayed passion influenced investment decisions in a roadshow setting. On the other hand, Shane et al. (2020) found that displayed passion affected the neural engagement of investors in entrepreneurship. Our findings fill the gap among these conflicting reports by considering both cognitive passion and emotional passion in a live streaming setting. Our results indicate that in a live streaming setting, both displayed passion and preparedness are important. The role of entrepreneurial passion is different in different settings.

Third, this study is the first to apply an electroencephalography inter-subject correlation (EEG-ISC) approach to analyze consumer engagement in a live streaming shopping context. It extends existing measurements of consumer engagement to the neural level. A majority of e-commerce studies are survey-based or use secondary data, for which participants were asked to report how they felt they had been engaged (e.g., Brodie et al., 2013) or directly observable behavior (e.g., Vivek et al., 2014). However, consumer engagement is a multi-dimensional concept that is difficult to represent with a single variable due to the richness of reflections on different platforms (Cheung et al., 2014). As cognitive engagement is a fundamental mechanism of behavioral engagement (Park and Lee, 2008), applying EEG-ISC to the study of live streaming e-commerce enhances the understanding of consumer engagement by objectively quantifying cognitive engagement in this context.

Practical contribution

This paper can inspire both broadcasters and MCN companies that nurture broadcasters. Our findings indicate the importance of entrepreneurial passion in motivating consumer engagement. Broadcasters should display a high level of passion during their live stream by using rich body language and facial expressions. They should also be diligent in their preparation before the live stream starts. For MCN companies, EEG-ISC provides a method of predicting consumer engagement before a formal live stream by detecting consumer neural engagement during a rehearsal, rather than monitoring consumer engagement behavior during the live stream. By comparing several rounds of different levels of displayed passion and preparedness, broadcasters could discover the most effective way to perform in live streaming videos.

Limitations and future directions

This study focused on live streaming e-commerce and our findings are limited to this context, although our findings complement the results of other EEG-ISC studies. Whether passion has a universal influence in other e-commerce scenarios remains unknown. Furthermore, to avoid the effects of individual preference, we only used videos about food products as our stimulus materials. Whether the attributes of products influence consumer engagement also remains unknown and requires further study.

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 Technological Ethics Committee of Shanghai University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

XY, YL, and WWe conceived and designed the experiments. WWe, YL, and WWa performed the experiments. KZ, WWe, and YL analyzed the data. YL, KZ, and XY wrote and refined the article. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by the Natural Science Foundation of China (71972126 and 71772117), the National Key Research and Development Program (2020YFB1708200), and the Innovation Program of Shanghai Municipal Education Commission (2019-01-07-00-09-E00078).

Acknowledgments

We thank the Parra Lab for sharing code and Professor Parra Lucas for helping by answering our doubts during the experiment.

Conflict of interest

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

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