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Navigating More than a Decade of Neuroscience Integration to Shape Business Strategies

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Abstract

Advances in theoretical knowledge have led neuroscience to intersect with social science, notably in the realm of neuromarketing—a sub-branch of social neuroscience. Within the past decade and looking back further, the field of neuromarketing has seen remarkable growth, highlighting the need for a comprehensive understanding of decision-making and consumer behavior by analyzing the brain's responses. Against this interdisciplinary backdrop, the study makes a significant contribution to the neuromarketing literature by conducting a systematic literature review over twelve years to explore the discipline's trends in topics and interests. A total of 72 studies were assessed and thoroughly investigated, revealing that the majority of interests in neuromarketing can be classified into five themes:

1. the evaluation of products and brands,
2. preferences for products and brands,
3. the evaluation of messages and communication,
4. the influence of others, and
5. purchase decisions.

This research offers suggestions to researchers and businesses on navigating the use of Electroencephalography (EEG), focusing on measuring neuronal responses directly, to enhance and extend traditional marketing methods. Moreover, it discusses their implications for the future of neuromarketing, contributing to marketing theory and practice.

Keywords: Neuromarketing, Neuroscience tool, electroencephalography, EEG

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Introduction

More than a decade after the landmark experiment with infant macaques, evidence demonstrates that mirror neuron activity influences the determination of goals, behaviors, and social interactions with others (Ferrari et al., 2009). Given the evolutionary link between humans and animals, this phenomenon observed in animals provides valuable insights into similar processes in humans. The experimental insight has not only propelled modern research but also facilitated rapid advancements by providing a bridge between neuroscience and consumer behavior. Consequently, this integration has transitioned seamlessly into the development of innovative marketing strategies and business opportunities. In fact, neuromarketing, which combines marketing, neuroscience, and psychology (Alsharif et al., 2023), has emerged as a respected approach to studying decision-making processes and consumer behavior, capturing unspoken cognitive and emotional responses (Halkiopoulos et al., 2022; Zhang et al., 2023).

Global neuromarketing has witnessed substantial expansion, with its market size reaching USD 3,324.98 million in 2023 and is projected to almost double, reaching USD 6,576.76 million by 2032, growing at a CAGR of 8.9% (Straits Research, 2023). Despite such progress, efforts to develop a comprehensive taxonomy for the neuromarketing literature are limited. The increasing trend in these methods suggests the need for new theoretical approaches to shape marketing strategies and the business industry. Moreover, most reviews provide an overview of neuromarketing by using various tools, both brain imaging tools (e.g., functional Magnetic Resonance Imaging; fMRI, Electroencephalography; EEG, Magnetoencephalography; MEG) and psychophysiological tools (e.g., Eye-Tracking, Skin Conductance Response). Unlike other studies, this research aims to conduct a systematic review on the field of neuromarketing, with a specific focus on a brain imaging tool to measure direct neural responses, namely EEG. Additionally, due to its valuable insights into consumer behavior, cost-effectiveness, and adaptability to diverse experimental settings approximating real-life, EEG is chosen as the primary focus. This systematic review seeks to draw conclusions regarding thematic interests and provide insights for future research.

The remainder of this study is organized as follows: Section 1 introduces the research objectives, focusing on investigating the application of EEG in neuromarketing and outlining its scope of use. Section 2 defines neuroscience and neuromarketing,

outlining the differences among non-invasive brain imaging tools. Section 3 describes the systematic literature review process, including the inclusion and exclusion criteria for paper selection. Section 4 discusses the main findings and summarizes the thematic trends. The conclusion and directions for future research are presented to underscore the implications for both research and practice.

Research's objective

1. To comprehensively investigate the diverse body of research employing electroencephalography (EEG) in neuromarketing.

2. To outline the scope of EEG use in neuromarketing and discuss future research directions based on a systematic examination of empirical studies.

Literature review

From Neuroscience to Neuromarketing

Neuroscience investigates the structure of human brain and its activity, i.e., how the nervous systems respond to stimuli (Kumar et al., 2024). It cooperates with interdisciplinary fields, such as cognitive science, affective science, social science, and marketing to advance our understanding of cognition and human behavior. To illustrate, cognitive neuroscientists seek to understand functions of the brain that correlate with information processing mechanisms, such as whether an individual perceives others' feelings (Ochsner & Lieberman, 2001). Affective neuroscience explores underlying moods and emotions (Davidson et al., 2002), whereas social neuroscience delves into how social psychological theory and methodologies contribute to a understanding broader neural function, particularly regarding the dynamic interactions between those neural networks involved in perception, cognition, and emotion within diverse social contexts (Forbes, 2015). Neuromarketing, which is a sub-branch of social neuroscience, addresses the primary question of how consumers' brains respond to marketing stimuli (Orzan et al., 2012).

Neuromarketing research is often metaphorically referred to as "opening the black box," shedding light on how unconscious reactions and emotions influence consumers' attitudes and decision-making processes (Mileti et al., 2016). Despite the interplay between the conscious and unconscious processes in decision-making, it has been determined that more than 90% of all information in a consumer's brain is processed unconsciously, underscoring the profound impact these unconscious processes have on decision-making (Agarwal & Dutta, 2015). Reinforcing this notion, a study examining 100 recent ads from 25 brands in the fast-moving consumer goods

industry found that ads scoring above average in a neuroscience experiment experienced a 23% increase in sales (Nielsen, 2016).

Given these insights from the neuromarketing research, it's important to compare these methods with traditional research techniques, like surveys and focus groups, which rely heavily on self-reported measures, and are thus controversial as participants may not always accurately express their feelings or perceptions, leading to data that does not fully capture their true reactions. In contrast, neuromarketing directly observe neuron activity, bypassing the limitations of self-reports. This approach provides a deeper understanding of consumer behavior, as it is not influenced by participants' desire to respond in socially acceptable ways (Dimoka et al., 2012). Thus, neuromarketing offers a more accurate picture compared to traditional methods, which are often compromised by untruthful responses.

Knowledge of brain function is extended by recognizing that different brain regions respond distinctly to various functions, such as cognition, motivation, perception, emotion, decision-making, and action. For example, neural activity in the prefrontal cortex (PFC) increases when individuals are presented with labeled products as compared to identical, unlabeled products (Meyerding & Mehlhose, 2020). Furthermore, when consumers consume and observe cues linked to strong cola brands, e.g., Coca-Cola and Pepsi, these brands elicit significantly higher activation in the PFC than weaker brands, e.g., Topstar and Vita Cola. To sum up, the extension of domain knowledge beyond traditional research methods, coupled with ongoing discoveries in brain region functions, positions neuromarketing as a powerful field poised to shape future marketing theories and practices.

Comparison of Non-Invasive Brain Imaging Tools

Functional Magnetic Resonance Imaging (fMRI), Magnetoencephalography (MEG), and Electroencephalography (EEG) are non-invasive brain imaging tools, indicating they function without necessitating physical penetration of the skull or cerebral tissue. These imaging tools are employed to capture neuron activities in distinct ways (Andersen et al., 2020; Luján et al., 2021). While fMRI indirectly measures neural activity through changes in the level of oxygen in blood flow, MEG and EEG directly capture brain activity by detecting the magnetic fields and electrical activities produced by neurons, respectively (Collinger et al., 2014; Shmuel & Maier, 2023; Teplan, 2002). In comparison to fMRI and MEG, EEG offers distinct advantages that make it a preferable for many neuromarketing studies. Table 1 represents a comparison of non-invasive brain imaging tools: fMRI, MEG, and EEG, illustrating the high-functionality and applicability of EEG.

First, EEG provides high temporal resolution, allowing researchers to capture brain activity with high precision in terms of timing (Dimoka et al., 2012; Luján et al., 2021). This precision enables the observation of rapid changes in neural activity, providing insights into real-time cognitive processes. Second, EEGs (e.g., Emotiv EPOC, NeuroSky MindWave Mobile, OpenBCI Ultracortex Mark IV) are lightweight and portable, allowing experiments to be conducted outside of laboratories, thereby facilitating research in close-to-real situations, such as detecting brain responses while a respondent is shopping (Zurawicki, 2010). Third, EEG has been selected for experimentation in various research studies like the prediction of consumer choices (Boksem & Smidts, 2015), cognitive engagement with product messages (Lee et al., 2014), and purchase decisions (Khushaba et al., 2013). Finally, the typical cost of EEG during experiments is approximately 2-5 times cheaper than other brain imaging tools, i.e., EEG ($100-200 per hour), fMRI ($200-500 per hour), and MEG ($200-400 per hour) (Dimoka et al., 2012).

Although the capacity of EEG may be limited by its unfavorable spatial resolution-specifically, the detection transmission information from deep brain sources (Luján et al., 2021), its ability to directly capture brain activity and temporal resolution, as well as its portability adaptability to real-life situations, and its cost-effectiveness, make it a primary tool in neuromarketing research.

Table 1 Shows comparison of non-invasive brain imaging techniques: fMRI, MEG, and EEG**.**

Criteria	fMRI	MEG	EEG
Measure Neural Activity	Indirect	Direct	Direct
Temporal Resolution	Low (2 or 3 seconds)	High (milliseconds)	High (milliseconds)
Portability	Not Portable	Portable	Portable
Close-to-Real Situations	No	No	Yes
Cost	High	High	Low
Spatial Resolution	High	High	Low

Methodology

A systematic search for articles published in English was conducted across the Emerald and ScienceDirect databases, spanning 2012 to 2023, utilizing “electroencephalography or EEG,” “marketing,” and “neuromarketing” as keywords. To maintain a focus on directly relevant findings, case studies, expert briefs, and review articles were excluded from the outset. This initial search resulted in 67 articles from Emerald and 107 from ScienceDirect, totaling 174 articles. A detailed review of the titles, abstracts, and content of these articles was then performed, after selecting only those empirical studies that utilized EEG in the context of marketing experiments. Studies incorporating other methodologies, such as eye-tracking, functional Magnetic Resonance Imaging (fMRI), electromyography (EMG), and skin conductance responses, without the inclusion of EEG, were excluded. Through this process, the compilation was refined to 72 articles deemed suitable for in-depth analysis. For a graphical depiction of the systematic research process, see Figure 1.

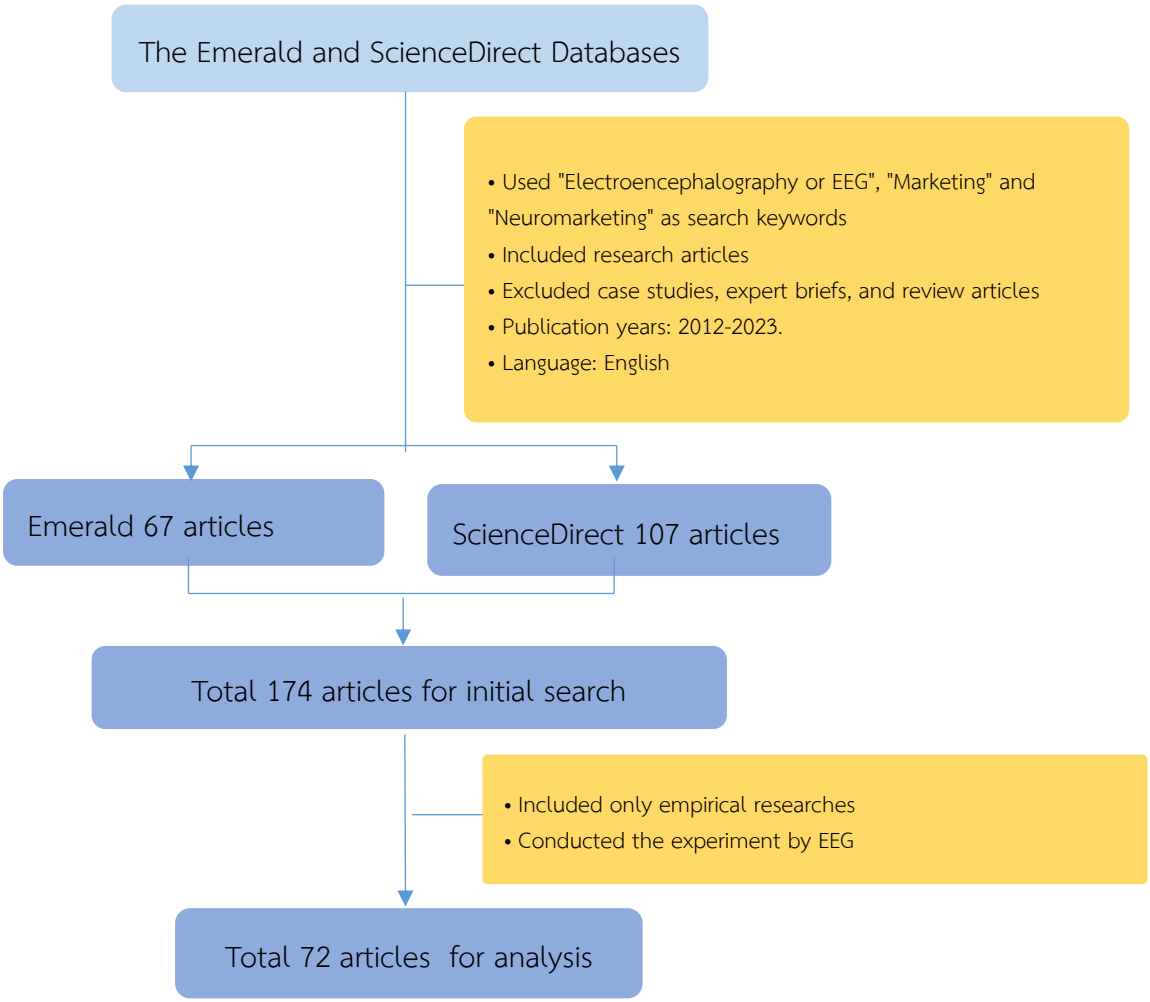

Figure 1 Illustrates systematic research process.

Results

To visually capture the evolving interest in neuromarketing research that employs EEG, Figure 2 tracks the publication frequency of articles from 2012 to 2023. The analysis of the initially identified 174 articles and the 72 articles subsequently selected for in-depth analysis similarly reveals a trend: a growing interest in integrating EEG into the marketing domain, highlighting a notable increase in research activity since 2018. While the integration of neuroscience into marketing from 2012 to 2017 remained consistently low, the subsequent years exhibited a marked rise. This uptick suggests a robust continuation of this trend over the last six years, reinforcing the increasing interest in the application of EEG within the neuromarketing field.

After observing the trends, a vast array of neuromarketing research areas has been systematically categorized into five principal research themes:

(1) evaluation of products and brands,

(2) preferences of products and brands,

(3) evaluation of messages and communication,

(4) the influence of others, and

(5) purchase decisions

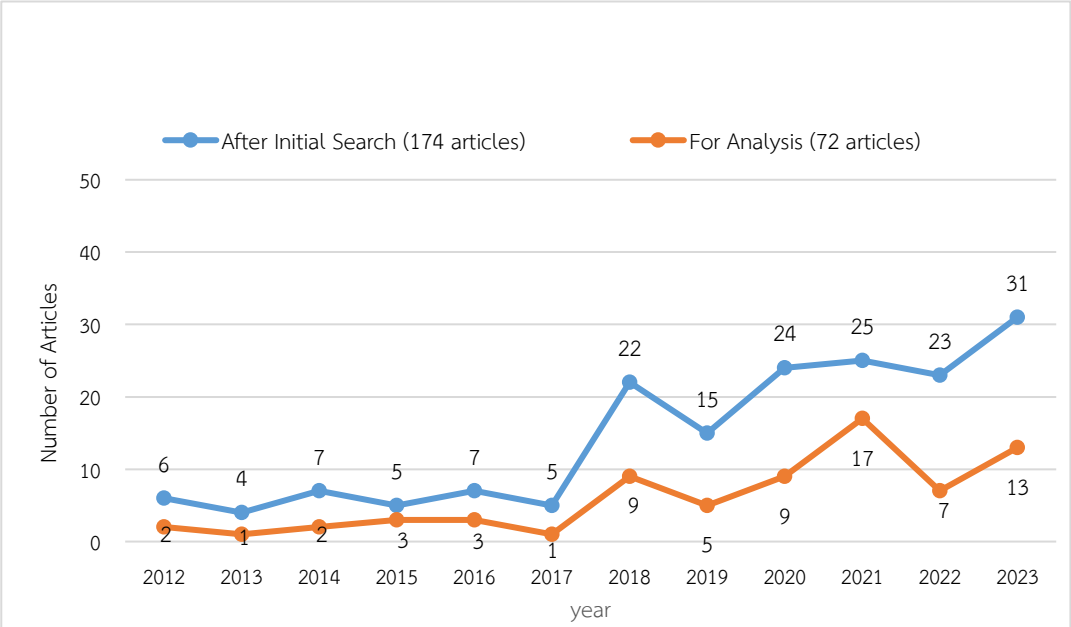

Figure 2 Tracking the Number of Articles on Neuromarketing from 2012 to 2023

Table 2 Shows five main research themes in current neuromarketing studies

No.	Theme
1	Evaluation of Products and Brands
2	Preferences of Products and Brands
3	Evaluation of Messages and Communication
4	The Influence of Others
5	Purchase Decisions

Theme 1: Evaluation of Products and Brands

The evaluation of products and brands in neuromarketing research is critical for deciphering consumer behavior, involving a complex interplay of cognitive evaluations, emotional responses, personality traits, and familiarity as they pertain to consumer attraction and decisions. This theme examines how individuals assess the merits, appeal, and characteristics of products and brands, thereby providing deep insights into the foundational mechanisms that influence consumer choices and allegiance. For example, an analysis of six product advertisements, categorized as either successful or unsuccessful, revealed differences in brain activation patterns. Specifically, successful advertisements were associated with lower activation in brain areas involved in uncertainty processing, working memory, and semantic evaluation, indicating they require less cognitive effort to process compared to unsuccessful advertisements, which demand higher cognitive effort (Daugherty et al., 2016). In a similar vein, the relatively new D-FLIP algorithm requires less cognitive engagement for completing tasks compared to traditional interfaces like Windows Explorer (Vi et al., 2014).

Where neuromarketing research has delved into the emotional responses elicited by stimuli, EEG signals were strongest when individuals were presented with stimuli containing positive emotional content, such as happiness (Parra Vargas et al., 2023). Additionally, the level of concern that evokes neural responses in users toward cybersecurity warnings varies by gender, emphasizing the need for effectively customized cybersecurity communications to accommodate diverse user groups (Anderson et al., 2015).

In addition to product evaluation, the evaluation of brands extends beyond cognitive processes to encompass personality traits and consumer attraction. To

illustrate, brands perceived as possessing a "competence" personality strongly attract consumers with high levels of openness, while those associated with traits such as "sincerity" and "ruggedness" may deter individuals with strong conscientiousness (Xu et al., 2023). To further explore the theme of evaluating products and brands, researchers have begun to examine these factors in combination rather than in isolation. For example, greater cognitive resources were devoted to evaluating less familiar brands and products within high-conflict categories, as indicated by increased N270 amplitudes in EEG signals, a correspondence that suggests that consumers may require more cognitive effort when evaluating unfamiliar brands or products in conflict-ridden categories (Ma et al., 2021).

Theme 2: Products and Brand Preference

The theme of product and brand preference delves into the neuroscientific understanding of consumer preferences for products and brands, revealing how individual choices are reflected in specific patterns of brain activity. It investigates the underlying neural mechanisms that differentiate preferred products from non-preferred ones, encompassing sensory perceptions, emotional connections, and even cultural influences, such as GI (geographical indications)—a sign used on products that denotes their origins and translates to a unique quality or reputation. Through neuromarketing studies, researchers can pinpoint the areas of the brain involved in the decision-making process, offering insights into why certain products appeal more to consumers than others. For instance, in a study on crackers, it was found that preferences are primarily associated with activity in the left frontal, temporal, and occipital regions of the brain. Interestingly, factors such as cracker flavor and toppings outweigh considerations of its shape (Khushaba et al., 2013). Furthermore, analysis of delta and theta waves revealed gender differences in coffee preferences, with men favoring coffee with GI information while women preferred without (Artêncio et al., 2022). The neuroscientific studies have demonstrated distinct brain activity patterns between preferred and non-preferred brands. For example, the late positive potential (LPP) on the right parietal cortex was significantly higher for preferred brands compared to non-preferred ones, suggesting differential neural processing of brand preferences (Bosshard et al., 2016).

Significantly, neuromarketing research goes further than individual preferences, venturing into predicting market-level outcomes. To illustrate, EEG technique is utilized to analyze spectral bands, beta and gamma, while participants watched movie trailers, and correlated these neural responses with subsequent box office sales, highlighting

the predictive power of EEG in forecasting consumer behavior on a larger scale (Boksem & Smidts, 2015).

Theme 3: Evaluation of Messages and Communication

This theme investigates how marketing communications are processed in the brain, emphasizing the effectiveness of messaging strategies from a neuromarketing perspective. It explores the cognitive and emotional responses elicited by various forms of communication, including green messaging, corporate social responsibility (CSR) initiatives, and digital marketing campaigns, to determine their impact on consumer behavior and decision-making.

For example, in a study concerning green consumption, EEG technology showed that consumers who prioritize sustainability exhibited higher theta wave activation, suggesting a deeper level of engagement with environmentally friendly messages (Lee et al., 2014). Similarly, CSR messages were found to increase theta activation in the anterior cingulate cortex, a brain region associated with empathy, leading to a heightened willingness to support pro-social products (Lee, 2016). This research makes theoretical contributions beyond traditional research, revealing that this phenomenon does not result from anxiety about social acceptance, but instead results from positive emotion (Aftanas & Golocheikine, 2001). In addition to eliciting positive emotions, EEG analyses have revealed that messages framed from a user-centric perspective enhance feelings of ownership and attention, subsequently simplifying the decision-making process. For example, individuals are more inclined to disclose personal information when authorization statements are presented from a user-centric rather than a platform-centric perspective (Luo et al., 2023). This positive inclination is because individuals experience a heightened sense of ownership over their data, which makes them pay less attention, thereby rendering the process of making decisions less complex.

Beyond simply observing brain waves and their patterns, prediction has been advanced to interpret and anticipate consumer actions within the digital marketing realm. To illustrate, the analysis of advanced brainwave patterns—specifically, those occurring within 300 milliseconds and detected in the bilateral temporal areas—enables the prediction of click-through rates and online consumer behavior (Zhang et al., 2021).

Theme 4: The Influence of Others

This theme explores the profound impact of the social environment and interpersonal interactions on consumer behavior. When considering social influence from reviews, brain responses to social commerce reviews from friends are more significant than responses to e-commerce reviews from unknown individuals (Bai et al.,

2015). This phenomenon highlights not merely the substantial influence peers exert on thought processes and decision-making, but also suggests that this effect is rooted in the increased ethos, or credibility, that peers hold. Their opinions are deemed more trustworthy, which influences judgments. Similarly, high volumes of reviews lead to increased perceived usefulness of products, with this effect being neurologically indicated by diminished negative N2 responses and increased positive LPP (Liu et al., 2021). Such findings point to a more favorable emotional and cognitive reaction to products with numerous reviews, suggesting the critical role of credibility and trust in shaping consumer behavior.

When integrating social influence into brand-related decision-making, especially in scenarios involving the presence of others (together versus alone) when comparing different brand types (luxury versus basic), the LPP in the centroparietal area for luxury brands is found to be greater than for basic brands among participants who are together, thus implying that the presence of others significantly influences the emotional response to a brand's product (Pozharliev et al., 2015). This finding reflects the desire for group membership, whereby individuals are motivated by the social recognition and status that come with choosing luxury brands in the presence of others.

Decisions influenced by social dynamics can manifest through forms of conformity, which can be divided into two categories: normative and informative conformity. Normative conformity involves complying to gain acceptance or avoid punishment, essentially driven by the desire to be liked. For instance, controllers are likely to falsify a financial report when experiencing pressure from their managers, a tendency that is associated with the functionality of the mirror neuron system (Eskenazi et al., 2016). In contrast, informative conformity is the acceptance of information about reality as gleaned from others, which leads to the desire to be right. Neural responses to “Buy” and “Like” deal information on group buying sites differ significantly, suggesting that the motivation behind “Buy” information, which reflects the desire to be right, is driven differently than “Like” information, representing the desire to be liked (Kuan et al., 2014).

Theme 5: Purchase Decisions

Neuromarketing has advanced in investigating the factors contributing to purchase decisions (Han et al., 2016). For example, emotional engagement plays a pivotal role in creating a pleasant shopping environment, which can enhance customer satisfaction and potentially increase sales. This engagement can be driven by ambiance elements, such as using LED accent lighting in lieu of halogen and fluorescent lighting (Berčík et al., 2015), and enlivening the shopping environment with music (Berčík et al.,

2016). Specifically, playing upbeat Slovak music has been found to increase sales of wines from Slovak regions by encouraging quicker movement through the store, leading to impulsive purchases from the Slovak wine selection.

In fact, neuromarketing studies have not only highlighted strategies to boost purchase intentions but have also explored how certain approaches can decrease the likelihood of a consumer making a purchase. For example, employing “trigger image” designs on packaging, such as those depicting the caloric content of alcoholic beverages, has been shown to reduce consumers' purchase intentions by eliciting negative emotions (Piper et al., 2021). These insights into purchase intentions could carry implications for addressing alcohol overconsumption, thereby informing strategies to deter impulsive alcohol purchases.

The manner in which information is presented can significantly influence the level of purchase intentions for the consumers. For instance, participants exhibited higher purchase intentions and shorter reaction times under positive framing conditions compared to those under negative framing conditions (Jin et al., 2017). This finding aligns with the research of Fu et al. (2019), which concluded that the truthful condition resulted in higher purchase rates and shorter reaction times than the deceptive condition. Correspondingly, electrophysiological results indicated a reduced N2 and an enlarged LPP in the truthful versus deceptive condition, suggesting less conflict and more positive evaluations in the truthful context. Additionally, choices between gift-giving promotions and discounts present a trade-off that can heighten consumer uncertainty and confound decision-making. Specifically, gift-giving promotions, due to their inherent information ambiguity, tend to reduce decision-making confidence because of the perceived associated risk, making them more challenging for consumers compared to discounts (Gong et al., 2018).

Indeed, advances in neuromarketing have emerged as an effective strategy in redefining business practices. Evidence from EEG studies reveals distinct brain patterns associated with both planned and unplanned purchases. There is a significant correlation between consumers' impulsiveness and their unplanned expenditures, as well as the number of unplanned purchases, suggesting that neuromarketing can aid marketers in creating engaging experiences that encourage customers to spend more time in virtual stores. Such engagement is anticipated to positively influence store satisfaction, variations in purchase quantities and amounts, and budget deviation (Kakaria et al., 2023).

Discussion and conclusions

Experiments utilizing EEG have become increasingly prevalent in the field of neuromarketing. Understanding the taxonomy of EEG application is crucial for monitoring trends in its usage. This study contributes to the existing literature by categorizing neuromarketing topics that use EEG in their experimental methodologies during the period from 2012 to 2023. Recent neuromarketing studies have been organized into five main research themes: (1) evaluation of products and brands, (2) preferences for products and brands, (3) evaluation of messages and communication, (4) the influence of others, and (5) purchase decisions. This systematic review not only lays the foundation for a deeper understanding of the intersection between neuroscience and marketing and its evolving trends but also outlines research guidelines and proposes various directions for future investigations and applications.

Recommendations

Three main areas have been identified that merit further exploration.

First, experiments in neuromarketing are crucial for enriching consumer marketing literature by delving into the brain activities that influence decision-making and consumer behavior. It is necessary to replicate, modify, or advance existing findings within each theme to uncover unconscious processes. Pushing the boundaries of neuromarketing further, it calls for examining group analyses, such as differences in culture (western vs. eastern), desire for group membership (inclusive vs. exclusive), social acceptance requirements (high vs. low), perceived risk (high vs. low), and technology readiness (high vs. low). Furthermore, addressing research questions across the identified themes can bridge existing gaps in the literature and foster the generation of novel research inquiries, thus expanding the scope and depth of the field.

Second, unlike previous research that focuses on studying neuronal activities and brain regions to understand consumer perception and attitude, there is imperative to integrate forecasting methods to broaden the scope of research. Incorporating machine learning techniques, such as Artificial Neural Networks, Support Vector Machines, and Random Forests, can propel future research towards predicting outcomes, including the number of ads viewed, consumer buying choices, and sales forecasts. This enhancement in decision-making capabilities benefits businesses by offering predictive insights instead of mere explanations.

Finally, while traditional quantitative research methods, such as surveys, offer broad insights into population-level trends, qualitative focus groups provide a deeper understanding of consumer attitudes, perceptions, motivations, and perspectives through natural interaction. However, both approaches may encounter limitations,

such as social desirability bias, which neuroscientific tools can potentially mitigate. Incorporating neuroscience in research comes with its own challenges, including the complexity of experimental setups, higher costs, and the need for specialized expertise to interpret the results. Yet if concerns about the limitations of neuroscience are minimized, comparing findings from neuroscience and traditional methods can greatly enhance our understanding of real-world phenomena, as well as foster innovation and yield practical insights.

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