

The Role and Application of Artificial Intelligence in Neuromarketing Research Based on Electroencephalography

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Abstract

Artificial Intelligence (AI) is a vital element of neuro-marketing research, which improves the process of identifying consumer preferences by using Electroencephalography technology. Employing AI algorithms allows marketers to record and decode brain signals elicited by marketing stimuli precisely. The synergy of AI and EEG in neuromarketing will bring about a revolution in the way marketers conduct research on consumer behavior. AI applications in neuromarketing are not limited to this; they also involve creating neural systems that adapt in real-time by collecting EEG data to alter marketing messages and content per consumer preferences. Moreover, AI can be employed to take over, simulate, and forecast consumer behavior and analyze emotional EEG data to achieve a deeper understanding of consumer behavior. This paper aims to provide preliminary information on the role of AI in neuromarketing using the EEG technique in two dimensions: tracking and processing of the EEG brain signals. The research on the role of AI in neuromarketing using a systematic literature review method is conducted. In summary, the joint utilization of AI and EEG techniques in neuromarketing research can provide us with more insights into consumer behavior, thereby supporting better marketing strategies.

Keywords: Artificial Intelligence, Neuromarketing Research, Electroencephalography

Introduction

Artificial intelligence (AI) has a central function in neuromarketing as it improves the analysis of consumers' preferences using EEG technology. By means of AI algorithms, marketers may capture and decode the brain signals in response to a marketing stimulus and can thus build up personalized strategies that differ from standardized approaches (Mashrur et al., 2023). AI technology, together with EEG data analysis, allows for precise prediction of the consumers'

ffective attitude (AA) and purchase intention (PI), which further helps in the creation of advertising campaigns with a targeting effect and a high level of impact on consumer decision making (Ishtiaque et al., 2023; Sourov et al., 2023). Moreover, AI can aid in the development of predictive models based on EEG data to classify consumer preferences, which is demonstrated in various research employing pattern recognition algorithms such as SVM, KNN, and NN (Bansal & Gupta, 2023). Alongside the integration of AI with neuromarketing, the comprehension of consumer behavior is expanded, and marketing strategies are improved. In fact, the intertwining of AI and neuromarketing can bring about benefits for marketers, such as enhancing strategies, increasing consumer engagement, and creating highly effective advertisements. In addition, artificial intelligence technologies, particularly neural networks, have demonstrated their ability to process data, predict trends, and solve problems related to marketing analytics, resulting in more precise segmentation, targeting, and effective positioning strategies (Tkáč & Verner, 2016). Besides, AI is able to add to the abilities of EEG in neuromarketing by scanning through large volumes of data and identifying patterns that may be hidden from human researchers (Ahmed et al., 2022). Instantaneously, AI algorithms can analyze EEG signals in real time, enabling marketers to change their strategies based on consumers' reactions immediately (Amin et al., 2020). AI in marketing is complex, yet its evolution is fast, and this shows its effectiveness in marketing. Marketing is currently the fourth-largest consumer of AI resources and the sixth-largest industrial adopter of AI technology, with approximately 2.55% of the total industry investment directed towards it (Bansal & Gupta, 2023).

The aim of this article is to provide initial knowledge on the role of artificial intelligence in neuromarketing, with attention paid to the EEG method. In neuromarketing research, data recording and data analysis are of great importance for marketers as they need to isolate the features from the extracted EEG data according to their research objectives. Incorporating artificial intelligence algorithms into data recording and analysis increases the precision of marketers and the usage of this approach in neuromarketing. Hence, marketers must amass information about the impact of artificial intelligence on neuromarketing, especially in the EEG technique. Consequently, this article examines the role of artificial intelligence in neuromarketing research based on the EEG technique in two areas: 1) Artificial Intelligence in the recording of EEG brain signals, and 2) Artificial Intelligence in the analysis of EEG brain signals. The examination of these two dimensions in neuromarketing furnishes marketers with an overall picture of the application of this method in market research, especially neuromarketing. To get an idea of the application of AI in neuromarketing studies using the EEG method, articles from the ScienceDirect website from 2020 to 2024 on the subject matter were found. A total of 101 scientific and review articles were analyzed out of all the articles found. Other options available here, like book chapters, encyclopedias, news, and other options, were not part of the bibliographic search. In a systematic search, the keywords and density of the articles related to the field of artificial intelligence in neuromarketing research were investigated. In this bibliometric search, articles related to the application of artificial intelligence in neuromarketing research were isolated, and then the isolated EEG-based articles were examined to determine the application of artificial intelligence in these types of research. This article is organized as follows: First, a bibliometric analysis of published research on artificial intelligence and neuromarketing was conducted. Then, the results of the analysis were used as a framework, and subsequently, a systematic literature review on the application of EEG in this type of research was conducted.

Literature Review*Artificial Intelligence in Neuromarketing and the EEG Technique*

The application of artificial intelligence-based tools has greatly benefited neuromarketing, providing valuable insights into consumer behavior, emotions, and preferences. With this information, marketers can create targeted and sustainable marketing campaigns that generate long-term value for the brand while minimizing negative environmental impacts (Papić et al., 2023). Neuromarketing is a relatively new consumer behavior and marketing research method for understanding the consumer mind, both conscious and unconscious, in order to determine what triggers the "buy" button in their minds. The visual and auditory aspects of a product or marketing advertisement that influence prioritization are the main focus of neuromarketing research (Khushaba et al., 2013; Sourov et al., 2023). The objective of neuromarketing is to identify the areas of the brain responsible for processing different stimuli, as well as the manner in which they are responded to and the influence of conscious reasoning on the decision-making process. Neuromarketing integrates neuroscience with marketing through the use of modern, non-invasive technologies (Guixeres et al., 2017; Nazari Ghazvini et al., 2023). This is achieved exclusively through the ethical utilization of neuroscience methodologies, with relevant consent forms duly signed by participants to preclude any legal complications (Sankary et al., 2023).

A prevalent instrument employed in neuromarketing is the electroencephalogram (EEG), which is employed for the acquisition of unprocessed cerebral signals. Digital signal processing techniques (e.g., artifact removal, filtering, data labeling) are employed to eliminate irrelevant or superfluous signal components and to segment the data into meaningful portions or data points (Chaddad et al., 2023). The data is divided into training and testing datasets, which contain the features that are significant for machine learning classification models using the data points. This model can then be used to predict consumer preferences and the subsequent successful design and production of products with higher sales. Over time, neuromarketing has played a role in many marketing strategies of tech companies (Google, Amazon, PayPal, etc.), automotive industries (Hyundai, etc.), food advertisements, and other industries. It is anticipated that this algorithm will become increasingly accurate. The classification of consumer choices, encompassing visual, auditory, pricing, packaging, and advertising aspects, is predicted to lead to further advancements and applications due to its immense potential. Various programs, such as websites employing neuromarketing to enhance ease of use and attractiveness, represent examples of this technology (Sourov et al., 2023).

Artificial intelligence (AI) is becoming an indispensable component of neuromarketing techniques, particularly in electroencephalography (EEG) analysis. It has been demonstrated that AI, particularly deep learning networks (DLNs) (Ishtiaque et al., 2023), can accurately predict consumer preferences, such as affective attitude and purchase intention, from EEG signals. Researchers have demonstrated the ability to attain high accuracy in the classification of positive and negative consumer preferences through the use of AI algorithms, such as SVMs, in conjunction with feature selection techniques applied to EEG data (Hakim et al., 2023). Furthermore, AI-based neural networks offer a cost-effective means of measuring emotional responses and cognitive patterns in marketing strategies, thereby reinforcing the efficacy of neuromarketing tools in the production sector (Fauzi & Widyarani, 2023). In

essence, the integration of AI with EEG technology in neuromarketing is anticipated to result in more precise and automated consumer behavior analysis.

Research Methodology

While the two axes of the research, namely recording and analyzing EEG signals in neuromarketing, have been explored, the library-based approach was used to investigate the application of artificial intelligence in neuromarketing. All papers in the artificial intelligence and EEG-based neuromarketing domain were searched, downloaded, and saved in EndNote software. Finally, the application of artificial intelligence in recording and analyzing EEG signals in neuromarketing was explored by giving special attention to the keywords of each article. In general, the following steps were taken to implement the library-based method in this research: In general, the following steps were taken to implement the library-based method in this research:

- Review of research keywords and terms, including artificial intelligence, neuromarketing, neuromarketing research, and EEG methodology.
- Download relevant articles and theses on the subject, with the last five years (2020-2024) being the focus.
- Extraction of the application of research dimensions based on two areas: 1) The function of artificial intelligence in picking up EEG brain signals, and 2) The role of artificial intelligence in analyzing EEG brain signals.
- The use of artificial intelligence for EEG-based neuromarketing will be assessed.

In the course of this investigation, the bibliography or bibliographic methods were employed from the ScienceDirect website due to its comprehensive coverage of the research topic and its accessibility relative to other databases. In this context, the research area of this study is neuromarketing. The ScienceDirect website provides access to all scientific articles (research articles), review articles (review articles), and books from 2020 to 2024, regardless of the journal type. Consequently, all such articles were reviewed. The subject matter is constrained to Computer Science (38), Business, Management and Accounting (37), Neuroscience (21), Psychology (13), and Social Sciences (10). Consequently, 89 scientific articles and 12 review articles were identified. The entered documents were imported into VOSviewer software without consideration of article type. VOSviewer is a software used for the construction and visualization of bibliometric networks. As an illustration, these networks may comprise research journals, researchers, or individual publications and may be constructed based on citations, bibliographic coupling, co-citation, or co-authorship relations. Additionally, VOSviewer offers a text mining function that can be employed to construct and visualize co-occurrence networks of the crucial terms extracted from scientific literature (VOSviewer official website, 2022). It is important to note that the software version employed was 1.6.18.

Results and Discussions

In the bibliometric analysis, considering the two main dimensions of research in neuromarketing studies, the role and application of artificial intelligence were examined in four areas: data mining, personalization, forecasting, and affective computing, which are defined and discussed in the context of neuromarketing.

VOSviewer program reported the Total link strength for neuromarketing, EEG, neuroscience, deep learning, emotion, consumer neuroscience, Electroencephalography (EEG), machine learning, and classification as 102, 86, 30, 29, 28, 27, 26, 25, and 20, respectively. Consequently, the extracted articles were examined in that order and clustered into four categories: data analytics, personalizing, predictive modeling, and sentiment analysis.

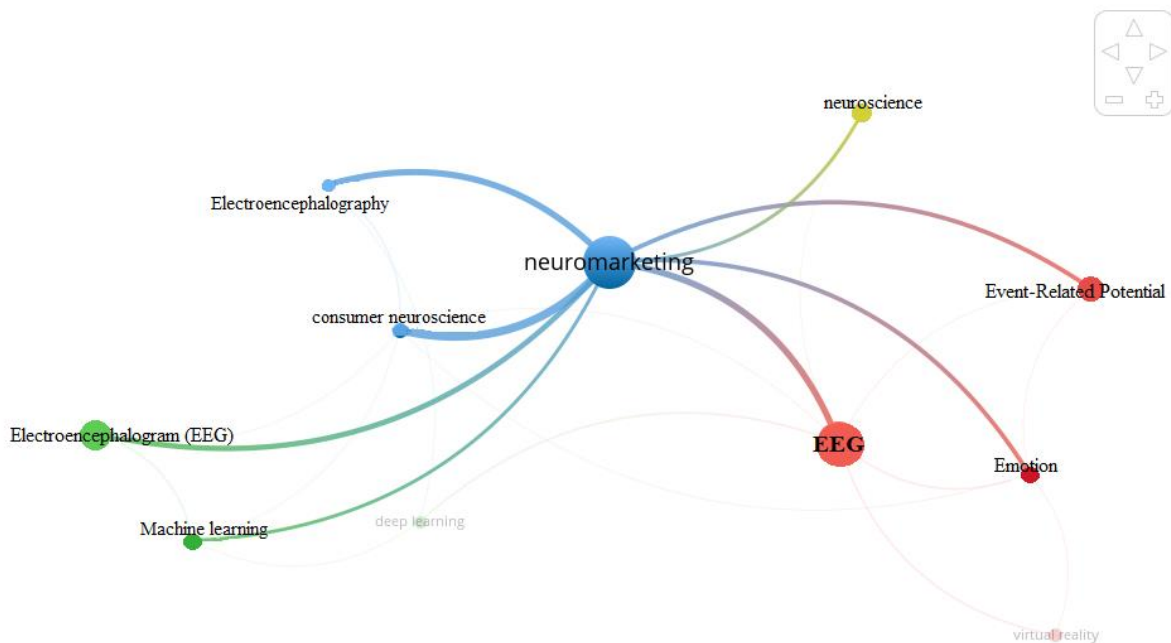


Figure 1. Neuromarketing Network of Artificial Intelligence, EEG Researches, on the Science Direct Site.

1. Data Analysis: Artificial intelligence (AI) algorithms are being used extensively to analyze EEG data in a number of applications (Hakim et al., 2023; Sourov et al., 2023; Usman et al., 2023) and have proven to be successful in many studies. Different approaches are being used, including the employment of fuzzy deep learning techniques for emotion recognition and classification (Kotte & Dabbakuti, 2023), the usage of signal processing and neural networks for the automated interpretation of EEG signals with high accuracy rates (Ndiku et al., 2022; Rahul et al., 2024), and machine learning algorithms. Learning algorithms and feature extraction techniques are effectively used to classify motion-related EEG signals (Ramírez-Arias et al., 2022). Besides, AI models like SCORE-AI have shown their potential to distinguish abnormal from normal EEG recordings and classify abnormal EEG patterns, providing a complete automated interpretation of routine EEGs (Tveit et al., 2023). These developments showcase the powerful capabilities of AI in improving EEG data analysis for various applications in neuroscience, brain-computer interfaces, and related areas. Techniques like fuzzy deep learning, wavelet transforms, and convolutional neural networks are being used to process and interpret EEG signals with a high accuracy rate between 88% and 97.9%. Through analyzing EEG data, AI algorithms can identify patterns and trends in consumer responses to marketing stimuli, helping marketers understand what parts of their campaigns are more inclined to attract customers.

2. Personalization: AI can be applied to monitor consumers' brain responses via EEG data and provide customized marketing strategies for them. It enables us to make marketing

campaigns that are more accurate and effective. AI algorithms can process big data in a way that traditional methods cannot, giving rise to unmatched customer insights that are impossible with conventional methods. On the other hand, interactions with consumers and consumer interaction theories are the basis on which AI develops personalized messages that are in line with the users' needs. However, the impact of AI on personalization will also be addressed to reveal the effect on consumer interaction and how it can give rise to much closer and more long-lasting ties, which will eventually lead consumers to be loyal to the brand. Artificial intelligence (AI) is the foundation of personalized marketing. It brings an individualized approach to both the content of the messages and their presentation. Therefore, it strengthens personalized relationships with consumers (Addula et al., 2024; Babatunde et al., 2024; Kumar et al., 2019). AI can utilize CRM data, purchase history, demographics, and past interactions to find out the interests of customers. These interests can be found in the pages they have viewed and the time spent on them (Ledro et al., 2023). Social media interactions like Likes, shares, and comments on social media sites determine customers' moods and brand loyalty. AI-based algorithms can identify hidden patterns and groups of customers that could have been overlooked. Conceive AI targets this crowd, which consists of people who have recently installed a fitness app and usually buy running shoes. This knowledge gives brands the ability to address customers individually, for example, in the form of personalized marketing messages, special discounts for running apparel, or exclusive tips related to their fitness goals (Cosmas Dominic et al., 2024).

3. Predictive Modeling: AI is able to develop predictive modeling, which the marketer will use to detect future advertising trends based on consumer behavior and the data collected from the customers' usage. By employing machine learning algorithms based on historical data, marketers aim to develop forecasting models that can spot consumer behavior, volatile market movements, and new advertising channels before they occur. It gives them the authority to act in advance through restructuring strategies, resource allocation in the most effective decision-making, and competition-leading. There is a specific focus on AI's effectiveness through real-world case studies and real-life demonstrations of its ability to detect things like these trends. AI has been put into use in the advertising industry in data collection, pattern recognition, analysis, and prediction, which in turn provides relevant information that enables decision-making, strategizing, and making the campaign flexible in an ever-changing advertising ecosystem (Haleem et al., 2022). AI, therefore, assists marketers in tracking and detecting the brand image with the help of natural language processing and sentiment analysis algorithms. Social media platforms, online reviews, and customer feedback can offer information about customer opinions on a brand to AI systems by providing valuable data. These findings will bring about an increase in brand recognition and notice the strong and weak sides of the product. AI makes it possible to perform competitor research that involves factors such as branding strategies, market positioning, consumer sentiments, and big data. AI algorithms retrieve information from many sources, including social media, news articles, and customer comments, to present a complete picture of what competitors are saying in the market. Thus, advertisers can make use of this information to identify market gaps, distinguish their brand from the competitors, and, eventually, create a methodology to possess an edge over the competitors. AI can be implemented to build models that can forecast future brand positioning and market trends (Cannella, 2018).

4. *Emotional analysis*: Emotions and affect play an outstanding role in marketing, as they affect the way we process information, react to persuasive messages, and evaluate the impact of marketing stimuli. Therefore, feelings play an important role in making the decision. Consumers sometimes find themselves in an information overload situation where they simply buy on impulse and without thinking. Emotions play a crucial role in marketing communication and product design, which is why marketers should take them into consideration while creating their marketing communication and product designs for a higher conversion rate. The gain of productivity, customer relationships, customer experience, and business utilization optimization (Poels & Dewitte, 2019) are the benefits. This means that AI is becoming more and more significant in the emotional examination of consumer behavior. Giving an example of studying consumer behavior is that the researchers can use electroencephalography (EEG) and quantitative electroencephalography (QEEG) heat maps (Nazari Ghazvini et al., 2023). Electroencephalography (EEG) enables researchers to visualize the emotional reactions of consumers at any given moment. AI can analyze EEG signals to see the emotional responses of consumers to marketing stimuli, and this will help marketers understand the affective influence of their marketing campaigns on consumers. Emotional analysis of consumer behavior by EEG measures the mental state of a consumer using EEG waveforms and wave software. Different waves in combination with different emotions can be achieved using different waves (Nazari Ghazvini et al., 2023). In fact, people who cannot communicate their emotions or gestures in order to identify their emotions by only voice, gestures, or body posture alone cannot do so. This implies that EEG is a viable approach to recovering human feelings, and it has been applied in different studies to understand human emotions (Vempati & Sharma, 2023).

The following table (Table1.) summarizes the bibliometric analysis of the application of artificial intelligence in the recording and analysis of EEG signals in neuromarketing:

Table1

Bibliometric Analysis Summary of the Application of Artificial Intelligence in EEG and Neuromarketing

Role	Summary
<i>Data Analysis</i>	Various approaches such as the use of fuzzy-based deep learning techniques to detect and classify emotions, the use of signal processing and neural networks to automatically interpret EEG signals at high precision rates
<i>Personalization</i>	AI algorithms have the power to analyze vast datasets and reveal hidden customer insights that are unattainable in traditional ways. The impact of AI on consumer engagement is analyzed and reveals how deeper connections ultimately reinforce and increase brand loyalty.
<i>Predictive Modeling</i>	By using machine learning algorithms for historical data, marketers can build predictive models that predict consumer behavior, market dynamics and emerging advertising channels. Artificial intelligence also allows marketers to analyze and monitor brand perception using natural language processing and analytics algorithms.
<i>Emotional analysis</i>	AI can analyze EEG signals to identify emotional responses to marketing triggers, helping marketers understand the emotional impact of their campaigns on consumers.

Conclusions

Artificial intelligence as a research tool in the area of neuromarketing gives marketers a chance to discover the patterns of customer behavior at a deeper level. AI is a fresh technology that is already used in neuromarketing research, and it provides a wide variety of advantages and possibilities to marketers. The incorporation of AI into business operations allows companies to make predictions from data analysis, increase customer service, and use targeted marketing, which will undoubtedly lead to increased returns on investments. Scientists' AI algorithms have analyzed EEG signals for several years. AI algorithms are known as a set of rules, methods, and machine operations applied to automate different activities and make decisions in AI. Such algorithms are driven by data analysis, pattern recognition, learning, and performing complicated tasks. Existing AI algorithms are classified into three categories: EEG-based neuromarketing research uses three data analysis techniques, namely, supervised learning, unsupervised learning, and reinforcement learning. These techniques are chosen based on the research goal and protocol design. Furthermore, few AI algorithms harness techniques like classification, regression, clustering, and neural networks. A classification algorithm splits data into separate classes or groups, whereas a regression predicts a continuous value from a set of numbers. In clustering, the data is classified into groups that are similar to each other, and neural networks, which are inspired by the structure of the human brain, are used in a variety of AI tasks.

On the other hand, companies are trying to improve customer service by providing more services and increasing competition in the market. AI-driven personalized recommendations are a solution that can be applied. Companies can be the most beneficial for everyone by collecting and analyzing data about customers. AI serves as a tool that enables businesses to do so with more precision. The company can know what products, services, pricing, and communication methods work best for each individual by means of data analysis. This

provides a pleasant shopping experience for customers and helps the companies attract more customers and increase their sales. Predictive analytics applies historical data, statistical algorithms, and machine learning techniques to predict the probability of future happenings. This methodology includes the discovery of patterns and trends through which forecasts are made and enabling businesses to be one step ahead of customers, market, and operations. Data is at the heart of predictive analytics. The quality and relevance of data directly relate to the accuracy of predictions. Data is sourced from various channels, such as customer relations, transaction records, and social media, in order to build predictive models. AI makes it possible to implement predictive analytics to a large extent by allowing businesses to customize and personalize customer experience based on their preferences and needs. AI-driven CRM systems can offer appropriate products, better timing for communications, and better customer satisfaction. AI-based EEG sentiment analysis is a tool that helps us understand both the cognitive and emotional aspects of communication. This allows them to use verbal and non-verbal cues to perceive and respond.

However, the combination of AI and EEG methods in neuromarketing research will widen the horizons of understanding consumer behavior and marketing strategy effectiveness. AI-based neural activity analysis and translation enable marketers to develop more customized and engaging experiences for their specific consumers, which in turn leads to increased market share.

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