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PAPER

Exploring the Path of Biomedical Technology in Consumer Neuroscience Research: A Comprehensive Bibliometric Analysis

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ABSTRACT

This study performs a comprehensive bibliometric analysis of biomedical (i.e., non-brain) technology such as eye-tracking (ET), electromyography (EMG), galvanic skin response (GSR), implicit association test (IAT), and electrocardiogram (ECG) tools in studying consumer' behavior. To achieve this aim, we adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol and bibliometric analysis (VOSviewer software) for extracting the relevant documents from the Web of Science (WOS) database between 2013 and June 2023. A total of 58 documents (fifty-one articles and seven review articles) were included in the analysis. The results showed an increasing trend in publications over the years—the top countries in terms of publication outcome were Spain (13 papers) and the USA (10 papers). The analysis also identified the most influential authors, such as Babiloni, F. and Cherubino, P. It was further analyzed for the most cited article, which is titled "Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials", and keywords related to neuromarketing and non-brain tools. Additionally, Frontiers in Psychology was determined as the most-productive journal. This bibliometric analysis reveals insights into the current state of non-brain tools research. It also provides insights into future research directions in the consumer neuroscience field. This study will provide general insights and details about current trends in consumer neuroscience research using biomedical technology.

KEYWORDS

neuromarketing, consumer neuroscience, bibliometric analysis, biomedical technology, WoS database

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1 INTRODUCTION

The field of neuromarketing has gained significant attention in recent years due to its potential to reveal the underlying mechanisms of consumer behavior [1–3]. Neuromarketing is a hybrid field that includes marketing, neuroscience, and psychology [4–7], which relies on advanced technologies. According to Bercea [8], the neuromarketing technology has been divided into three categories, as follows: (a) metabolic tools such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), (b) electrical tools such as electroencephalography (EEG), magnetoencephalography (MEG), steady-state topography (SST), and transcranial magnetic stimulation (TMS), and (c) non-brain tools such as eye-tracking (ET), electromyography (EMG), galvanic skin response (GSR), implicit association test (IAT), and electrocardiogram (ECG). Metabolic tools have been used to record the neural responses of the cognitive and emotional responses toward the marketing mix [1, 9, 10]. Electrical tools have been used to record the electrical activity signals of the brain toward marketing activities [11]. Non-brain tools have been used to measure the emotional responses of consumer, such as visual fixation, attitude, pupil dilation, eye-movements, sweating level, and heart rate [12, 13]. The researchers have used non-brain tools to study the consumer responses toward marketing stimuli such as ads, products, prices, and brands due to their less cost [8, 14, 15].

EMG is a non-brain tool and convenient to measure the emotional valence and arousal [16], focusing on both visible and hidden facial muscles, including the zygomatic and corrugator muscles [17–19]. Moreover, it enables the measurement and identification of physiological properties of facial muscles, encompassing voluntary and involuntary responses [20, 21]. Activation of the zygomatic muscles is associated with positive stimuli and can influence purchasing decisions [22, 23]. Conversely, the corrugator muscles are linked to negative stimuli [19, 24].

GSR and ECG are used to measure the emotional responses toward marketing stimuli. GSR is a promising tool for measuring emotional dimensions and autonomic nervous system activity in consumer research. GSR has emerged as a valuable tool for measuring emotional dimensions, such as valence and arousal, and capturing changes in skin conductance and sweat gland activity [25–27]. ECG is employed to measure heart rate (HR) and heart rate variability (HRV) [28, 29]. During exposure to marketing stimuli, ECG can record the activations of the heartbeat [27, 29]. Heart rate is commonly regarded as a reliable indicator of emotional valence, where a temporary slowdown of the heartbeat is associated with both positive and negative emotions, while sustained positive stimuli increase heart rate, and the opposite is also true [30]. By utilizing both GSR and ECG, it is possible to identify autonomic activity and determine the emotional state of consumers.

ET, or eye tracking, is utilized to capture and analyze the eye movements of individuals as they engage with various marketing stimuli, including advertisements, products, and brands. This technology provides valuable insights into the subconscious and unconscious behaviors exhibited by consumers Cherubino, et al. [12]. Given the established correlation between visual attention and eye movements, ET serves as a beneficial tool for experimental psychology and neurological research [31]. As outlined by Chavaglia, et al. [32], ET enables the recording of where individuals are looking, the duration of fixations, changes in pupil dilation, the level of focus, and specific eye movements, thereby providing information about particular areas of interests (AOIs) [33].

The Implicit Association Test (IAT) is a measurement tool used to assess customers' attitudes towards brands or advertising [34]. It operates by requiring participants

to select positive or negative words displayed at the bottom of the screen, thereby reflecting emotional valences, such as pleasure or displeasure, sadness or excitement [35]. By analyzing customers' reaction times, the IAT can uncover their attitudes towards marketing stimuli, including brands and ads, such as preferences or dislikes [23]. Moreover, the IAT serves as an indirect approach to capture and predict customers' unconscious behaviors or attitudes towards brands and ads, thus circumventing the limitations of relying solely on surveys to gain insight into inner knowledge about customer attitudes [36]. Consequently, the IAT facilitates the comparison of customer attitudes towards two different brands or ads by monitoring the reaction time of each customer, offering valuable insights to researchers and marketers [34].

Aware of the growing interest in neuromarketing, several studies analyzing scientific production on neuromarketing have already been published [37, 38]. However, no previous research was performed to map the ("neuromarketing OR consumer neuroscience") AND ((eye*tracking OR ET) OR (galvanic skin response OR GSR) OR (electrocardiogram OR ECG) OR (electromyography OR EMG) OR (implicit association test OR IAT)) research production in the Web of Science (WOS) database. Therefore, this study differs from other review papers concentrating on the global academic research trends of studies that used ET, GSR, ECG, EMG, and IAT tools in neuromarketing or consumer neuroscience research between 2013 and 2023 on the WOS database. To this end, this study tries to fill the gap in scientific literature. This study aims to provide a comprehensive bibliometric analysis of the ("neuromarketing OR consumer neuroscience") AND ((eye*tracking OR ET) OR (galvanic skin response OR GSR) OR (electrocardiogram OR ECG) OR (electromyography OR EMG) OR (implicit association test OR IAT)) identifying the most prolific countries, academic institutions, authors, and journals. In addition, the articles having the highest numbers of citations, the co-citation network of authors and papers, and the hot keywords with occurrences will be determined. The main contributions and steps of this bibliometric analysis study are summarized and listed as follows:

- To provide an overview of the EMG, GSR, ECG, ET, and IAT tools extensively utilized in marketing research.
- To identify the growth of annual scientific publications based on journals' outputs.
- To identify the overall performance, such as productive countries, institutions, journals, and authors.
- To identify the most prominent themes/keywords in the (neuromarketing OR consumer neuroscience) AND ((eye*tracking OR ET) OR (galvanic skin response OR GSR) OR (electrocardiogram OR ECG) OR (electromyography OR EMG) OR (implicit association test OR IAT)).
- To identify the most-cited articles to be considered in future studies.
- To provide new references and directions to scholars who are interested in (neuromarketing OR consumer neuroscience) AND ((eye*tracking OR ET) OR (galvanic skin response OR GSR) OR (electrocardiogram OR ECG) OR (electromyography OR EMG) OR (implicit association test OR IAT)).

The structure of this research is as follows: Section 2 outlines the methodology employed in this study. Section 3 is concerned with a bibliometric analysis of pertinent literature. Section 4 discusses the results of the paper. Section 5 provides concise conclusions. Finally, Section 6 presents the study's limitations and potential future directions.

2 MATERIALS AND METHODS

To conduct this review, the study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, which ensured the identification of relevant papers [39]. In order to achieve the objective of this study, a bibliometric analysis was employed. This approach allowed for the identification and examination of global research trends in the field of neuromarketing, including the most productive countries, academic institutions, journals, authors, highly cited papers, and keyword occurrences, all of which serve as indicators for assessing the progress in publications. The primary aim of this study is to provide an overview of current trends and address any existing gaps in the literature.

To accomplish this, four research questions were formulated to guide the structure of the analysis and gain a comprehensive understanding of the existing scientific research in the analyzed domain, as follows:

RQ1: Is there and what is the annual growth of scientific publications in the field?
RQ2: What are the prominent "a) countries; b) academic institutions; c) journals; d) authors"?
RQ3: What are the most prominent keywords in selected articles?
RQ4: What are the most-cited articles in the field?

Endeavoring to answer the research questions, the current study starts by extracting articles from the WoS database in June 2023. In addition, this study has followed the instruction of [40] to present a thorough bibliometric analysis detecting and listing "the prominent countries, institutions, journals, and authors"; later on, a brief description of each analyzed parameter is provided. The VOSviewer software was utilized to create visualization maps, which simplifies bibliometric research across various fields, including neuromarketing [2]. In particular, VOSviewer has been used in several studies related to neuromarketing [37, 41], Services quality [42, 43] to gain a comprehensive understanding of the development of using ET, GSR, ECG, EMG, and IAT tools in this field.

In June 2023, data was gathered from the Web of Science (WOS) database for this study. The primary focus was on articles and reviews that utilized various tools in marketing research, namely ET, GSR, ECG, EMG, and IAT. Through this process, a total of fifty-eight papers were identified, all of which were published between 2013 and June 2023. This paper specifically targeted documents (articles and reviews) that employed these tools within the aforementioned timeframe, as there has been a notable increase in the number of publications related to these techniques. Furthermore, the selection process was limited to English papers, given the widespread use of English language in academic publications. The goal of this study was to gather as many papers as possible to comprehensively explore and highlight the global academic trends in utilizing ET, GSR, ECG, EMG, and IAT tools in marketing research activities. Figure 1 illustrates the selection process followed in this study, and the papers included in the analysis had to meet specific characteristics as outlined below:

- "Method: ET, GSR, ECG, EMG, and IAT"
- "Publication year: 2013 to 2023"

- "Language: English"
- "Document type: article (51 papers) and review (7 papers) (Proceeding paper (2) and editorials (1) were excluded)"

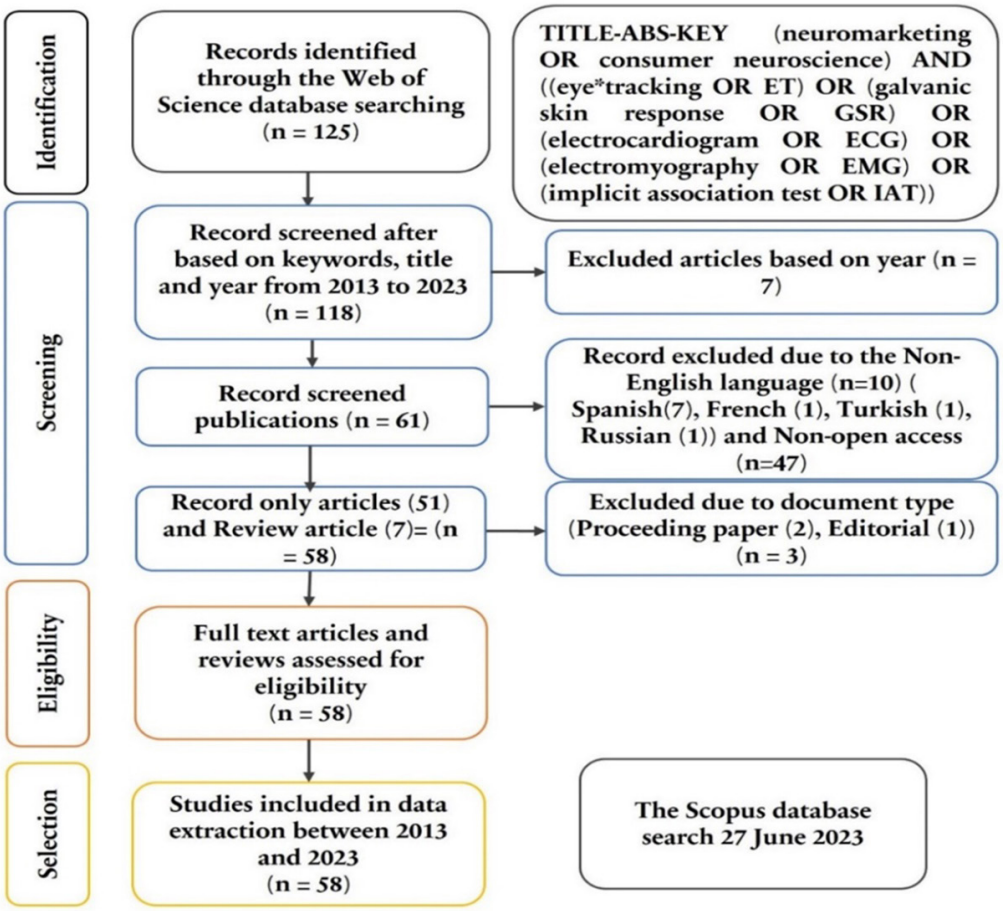

Fig. 1. PRISMA process for extracting documents

3 RESULTS

As a result of the procedure, 58 academic journal papers that utilized ET, GSR, ECG, EMG, and IAT tools in marketing research were identified. The analysis revealed a significant growth in publications, with over 50% of the total papers being published in the last four years, from 2020 to 2023. Figure 2 illustrates the annual publications published between 2013 and 2023, with one paper being published in 2013 and the number increasing almost sixteen-fold in 2020 before slightly decreasing to 10 papers in 2022. The increasing interest among scholars in neuromarketing has led to a rise in the publications and interest in using ET, GSR, ECG, EMG, and IAT tools in marketing research due to the less cost of these tools than fMRI, EEG, and PET.

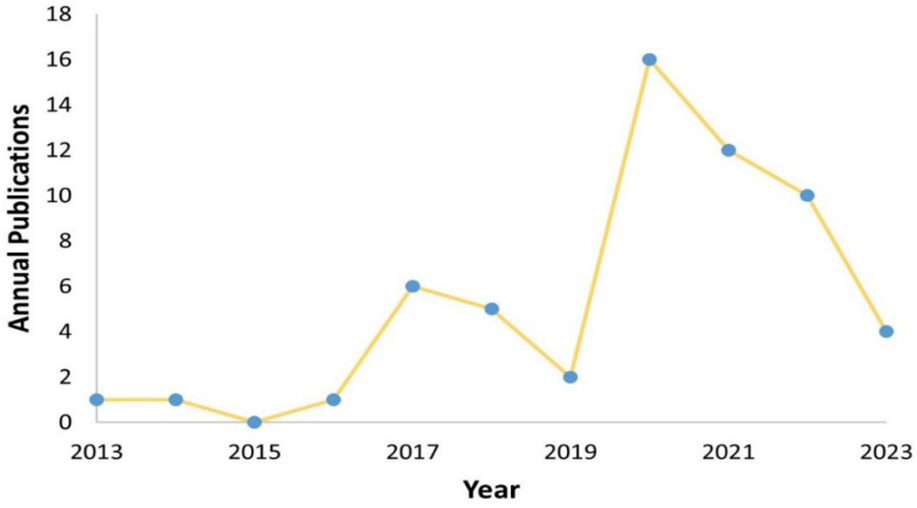

Fig. 2. The annual publications between 2013 and 2023

3.1 A bibliometric analysis

Leading countries and institutions. The analysis revealed that the ten prominent countries could be classified into three groups based on their productivity levels. The first group consists of two countries (e.g., Spain and USA) that produced at least ten papers, the second group consists of three countries (e.g., Italy, KSA, and England) that published between five and ten papers, and the third group consists of five countries (e.g., Malaysia, Australia, Germany, China, and Japan) that produced between five and two papers. As depicted in Table 1, Spain, the USA, Italy, and KSA have collectively contributed to more than half of the total papers since 2013. Specifically, Spain has been the most productive country, with thirteen documents and the second highest-cited document, with 155 total citations (TCs). Although Italy has published eight papers, its papers have the most-cited documents, with 194 TCs. In addition, KSA is in the 4th level in the list; KSA has published the third highest-cited documents, with 120 TCs. Japan is located at the tail of the ten prominent countries with two documents, but it has the sixth highest-cited documents with 53 TCs.

Table 1. The ten prominent countries

#	Country	TPs	TCs
1	Spain	13	155
2	USA	10	44
3	Italy	8	194
4	KSA	7	120
5	England	5	98
6	Malaysia	4	99
7	Australia	4	11
8	Germany	3	47
9	China	3	9
10	Japan	2	53

Notes: TPs: total publication, TCs: total citations, KSA: Kingdom of Saudi Arabia.

The Complutense University of Madrid, a prominent institute in Spain, has published six papers with the third highest-cited documents (59 TCs). However, the BrainSigns SRL Institute (Italy) produced four documents. It has the highest-cited documents (116 TCs). The 3rd institute is King Saud University (KSA), which has published four documents with 76TCs. Despite being at 6th position in the list, Universiti Teknologi Malaysia (Malaysia) has published three documents with the fourth highest-cited documents (56 TCs). At the bottom of the list, Imam Mohammad Ibn Saud Islamic University, has contributed two papers with 12 TCs (see Table 2).

Table 2. The most ten productive academic institutions of neuromarketing research

#	The Most Prolific Academic Institutions	TPs	TCs	Country
1	Complutense University of Madrid	6	59	Spain
2	BrainSigns SRL	4	116	Italy
3	King Saud University	4	76	KSA
4	Universitat Politecnica De Valencia	4	51	Spain
5	Sapienza University Rome	3	52	Italy
6	Universiti Teknologi Malaysia	3	56	Malaysia
7	Taif University	3	44	KSA
8	University Alicante	3	35	Spain
9	O.M. Beketov National University of Urban Economy in Kharkiv	2	20	Ukraine
10	Imam Mohammad Ibn Saud Islamic University	2	12	KSA

Productive journals. Table 3 shows the ten prominent journals that have produced documents that used ET, GSR, ECG, EMG, and IAT tools in neuromarketing research. The prominent journal is Frontiers in Psychology, which has published eight documents with 108 TCs. Frontiers in Human Neuroscience is the second productive journal that has published four documents, with 39 TCs. The 3rd journal in the list is Behavioral Sciences, with three documents and 16 TCS. Applied Science Basel, Frontiers in Neuroscience, Brain Sciences, and Sensors have published two documents each, with 55, 27, 6, and 0 TCs, respectively. The remaining journals have published one document each. Although Computational and Mathematical Methods in Medicine is located in 9th position in the list, it has published the highest-cited document (64 citations), titled "Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials". This is followed by Applied Science Basel, which is located in 4th position in the list, which has published the second highest-cited document, titled "Deep Learning for EEG-Based Preference Classification in Neuromarketing". Despite being the most productive journal, Frontiers in Psychology has published the third highest-cited document (48 TCs), titled "Beyond Self-Report: A Review of Physiological and Neuroscientific Methods to Investigate Consumer Behavior". At the bottom of the list is the Cogent Business Management journal, which has published one document with the fifth highest-cited document, titled "Neuromarketing research in the last five years: a bibliometric analysis".

Table 3. The most ten productive journals in neuromarketing and consumer neuroscience research

Source/ Journal	TPs	TCs	Title of the Most Cited Document	Time Cited
Frontiers in Psychology	8	108	"Beyond Self-Report: A Review of Physiological and Neuroscientific Methods to Investigate Consumer Behavior"	48
Frontiers in Human Neuroscience	4	39	"tDCS for Memory Enhancement: Analysis of the Speculative Aspects of Ethical Issues"	19
Behavioral Sciences	3	16	"The Influence of Price on Purchase Intentions: Comparative Study between Cognitive, Sensory, and Neurophysiological Experiments"	8
Applied Science Basel	2	55	"Deep Learning for EEG-Based Preference Classification in Neuromarketing"	54
Frontiers in Neuroscience	2	27	"Picking Your Brains: Where and How Neuroscience Tools Can Enhance Marketing Research"	26
Sensors	2	6	"The Sample Size Matters: To What Extent the Participant Reduction Affects the Outcomes of a Neuroscientific Research. A Case-Study in Neuromarketing Field"	6
Brain Sciences	2	0	"Systematic Review and Future Direction of Neuro-Tourism Research"	0
Biological Psychology	1	43	"Neural signals of selective attention are modulated by subjective preferences and buying decisions in a virtual shopping task"	43
Computational and Mathematical Methods in Medicine	1	64	"Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials"	64
Cogent Business Management	1	28	"Neuromarketing research in the last five years: a bibliometric analysis"	28

Productive authors. Table 4 displays the most prolific authors in neuromarketing research with the highest number of documents. Ten authors from four different countries and eight different academic institutions were identified. It has been noticed that four authors belong to Italy, Babiloni, F.; Trettel, A.; Cherubino, P.; and Maglione, AG. In addition, three authors belong to KSA, Al-Nafjan, A.; Aldayel, M.; Ykhlef, M.; followed by two authors belonging to Spain, Manas-Viniegra, L. and Tur-vines, V. Finally, only one author belongs to Malaysia, Alsharif, A. H. Two authors have produced four documents each, seven authors have published three documents each, and one author has released one document. As can be seen from Table 4, Babiloni, F. and Cherubino, P. are the most productive authors, with four documents each and are affiliated with Sapienza University Rome (Italy) and BrainSigns SRL (Italy) with 116 TCs each. Followed by Trettel, A. (76 TCs), Ykhlef, M. (76 TCs), Al-Nafjan, A. (66 TCs), Aldayel, M. (66 TCs), Alsharif, A. H. (56 TCs), Tur-vines, V. (35 TCs), and Manas-Viniegra, L. (28 TCs), who produced two documents each. Finally, although Maglione, AG. has produced two documents, she has the highest cited authors.

Table 4. The most ten productive authors

Author's Name	TPs	TCs	Affiliation	Country
Babiloni, F.	4	116	Sapienza University Rome	Italy
Cherubino, P.	4	116	BrainSigns SRL	Italy
Trettel, A.	3	76	Sapienza University Rome	Italy
Ykhlef, M.	3	76	King Saud University	KSA
Al-Nafjan, A.	3	66	Imam Mohammad Ibn Saud University	KSA
Aldayel, M.	3	66	King Saud University	KSA
Alsharif, A. H.	3	56	University of Technology Malaysia	Malaysia
Tur-vines, V.	3	35	University Alicante	Spain
Manas-Viniegra, L.	3	28	Complutense University of Madrid	Spain
Maglione, AG.	2	104	Sapienza University Rome	Italy

Keywords. In the field of bibliometric analysis, keyword occurrences serve as a quantitative measure to indicate the strength of connections between paired keywords, with a higher number denoting a stronger link. This analytical approach allows for a comprehensive understanding of the content of an article. The link strength between keywords reflects their frequency within the article, while the total number of links represents the overall occurrences of keywords throughout the article. In the present study, an author keywords co-occurrence analysis was conducted using the VOSviewer software. This analysis involved 34 keywords that appeared at least twice within the article. This methodology is valuable for presenting overarching findings about the content of the article and evaluating thematic trends within a specific subject area, such as neuromarketing. Figure 3 depicts these findings.

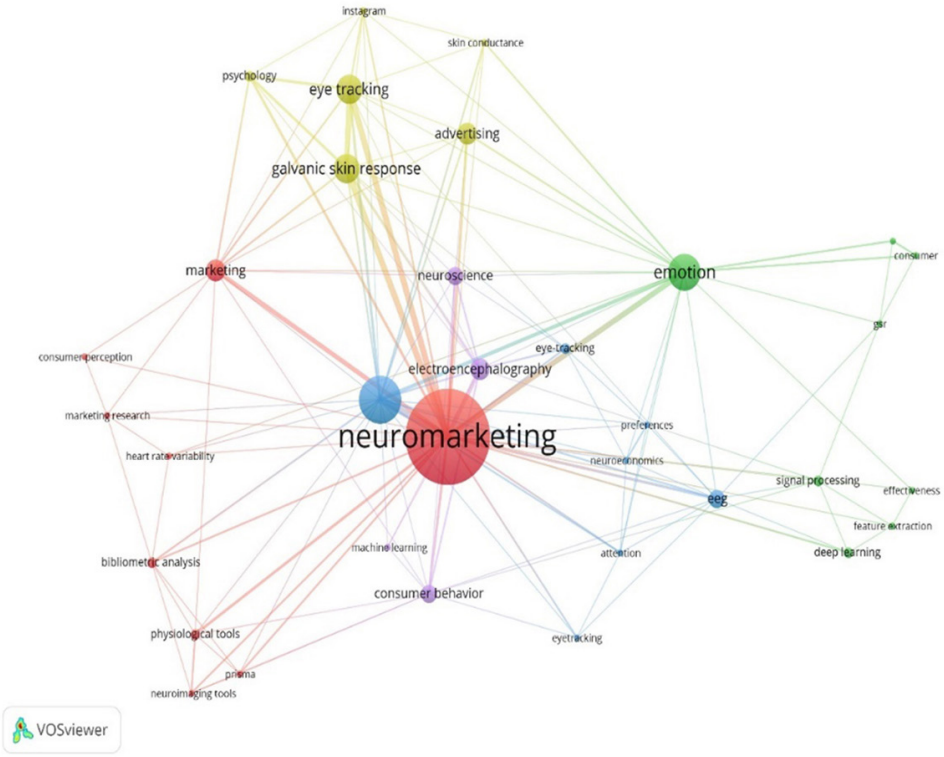

Fig. 3. Map of authors' keywords with two occurrences at least

Table 5 provides an overview of the most frequently used keywords that have appeared at least twice in the data. The term "Neuromarketing" has the highest frequency, with 26 occurrences and 82 total-link-strength, followed by the terms "Consumer neuroscience" and "Eye tracking", with 13 occurrences each. Neuromarketing and consumer neuroscience fields have utilized eye tracking, galvanic skin response, and electroencephalography tools to investigate and comprehend consumer behavior, emotion, attention, and preference toward marketing stimuli such as advertising. The term "consumer behavior" has been used five times with 15 total-link-strength, "emotion" has been used ten times with 31 total-link-strength, "attention" has been used two times with nine total-link-strength, and "preference" has been used two times with eight total-link-strength. Similarly, the term "advertising" has appeared six times with 12 total-link-strength.

Table 5. Top twenty authors' keywords with two occurrences at least

#	Keyword	Occurrences	TLS
1	Neuromarketing	26	82
2	Consumer neuroscience	13	41
3	Eye tracking	13	42
4	Electroencephalography	11	36
5	Galvanic skin response	12	41
6	Emotion	10	31
7	Marketing	6	20
8	Advertising	6	12
9	Consumer behavior	5	15
10	Neuroscience	5	12
11	Psychology	3	13
12	Physiological tools	3	10
13	Bibliometric analysis	3	9
14	Signal processing	3	7
15	Deep learning	3	5
16	Instagram	2	10
17	Attention	2	9
18	Neuroeconomics	2	8
19	Preference	2	8
20	Neuroimaging tools	2	7

Note: TLS: total-link-strength.

Citations. Analyzing citations is crucial for gaining insights into global trends in a specific field, such as neuromarketing and advertising, as it provides valuable information about the most frequently cited papers. This information can be used by future researchers or practitioners to identify impactful articles. In this study, we analyzed a total of 58 documents that used ET, GSR, ECG, EMG, and IAT tools in neuromarketing research and identified the most frequently cited articles

in Table 6, with minimum16 total citations (TCs), which investigated consumer behavior in response (e.g., emotion, attention, and preference) to marketing stimuli such as advertising. Table 6 shows that two documents had over 50 TCs. The article titled "Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials" and "Deep Learning for EEG-Based Preference Classification in Neuromarketing", which used GSR, HR, and EEG tools and were published by the Computational and Mathematical Methods in Medicine and Applied Sciences-Basel, were the most cited articles with 64 and 54 TCs, respectively. Furthermore, three documents had between 40 to 50 TCs, as follows: "Beyond Self-Report: A Review of Physiological and Neuroscientific Methods to Investigate Consumer Behavior", "Neural signals of selective attention are modulated by subjective preferences and buying decisions in a virtual shopping task", and "Electroencephalographic, Heart Rate, and Galvanic Skin Response Assessment for an Advertising Perception Study: Application to Antismoking Public Service Announcements", with 48, 43, and 40 TCS, respectively. The remaining documents had less than 40 TCs.

Table 6. The top cited document (minimum 16 citations)

Paper	Journal	Type	TCs
"Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials"	Computational And Mathematical Methods in Medicine	AR	64
"Deep Learning for EEG-Based Preference Classification in Neuromarketing"	Applied Sciences-Basel	AR	54
"Beyond Self-Report: A Review of Physiological and Neuroscientific Methods to Investigate Consumer Behavior"	Frontiers in Psychology	RE	48
"Neural signals of selective attention are modulated by subjective preferences and buying decisions in a virtual shopping task"	Biological Psychology	AR	43
"Electroencephalographic, Heart Rate, and Galvanic Skin Response Assessment for an Advertising Perception Study: Application to Antismoking Public Service Announcements"	Journal of Visualized Experiments	AR	40
"Evaluation of Emotional Responses to Television Advertising through Neuromarketing"	Communicar	AR	37
"A Comparison of Physiological Signal Analysis Techniques and Classifiers for Automatic Emotional Evaluation of Audiovisual Contents"	Frontiers in Computational Neuroscience	AR	31
"Neuromarketing research in the last five years: a bibliometric analysis"	Cogent Business & Management	RE	28
"Picking Your Brains: Where and How Neuroscience Tools Can Enhance Marketing Research"	Frontiers in Neuroscience	RE	26
"tDCS for Memory Enhancement: Analysis of the Speculative Aspects of Ethical Issues"	Frontiers in Human Neuroscience	AR	19
"A global research trends of neuromarketing 2015–2020"	Revista De Comunicacion-Peru	RE	16

Notes: RE; review, AR; article.

Bibliographic coupling (Authors). To determine the correlation strength between two authors, the VOSviewer tool was utilized in this study. It accomplished this by establishing bibliographic coupling, which measures the link strength between references associated with both authors [44]. The link strengths, indicating the degree of correlation, are presented in Table 7. A higher number of links signifies a stronger connection between the two references. Notably, the

analysis revealed that the most robust correlation was observed between Babiloni, F. and Cherubino, P., with 373 links. Following closely was the connection between Cherubino, P. and Trettel, A., with 256 links. The third strongest links were identified between Al-Nafjan, A. and Aldayel, M., with 220 links. The links between Maglione, A. and Trettel, A. were 95 links, while the strength of the link between Trettel, A. and Ykhlef, M. were 24 links, the weakest links between the two authors.

Table 7. The top authors pair with minimum documents (2) and citations of authors (46)

#	Item 1	Item 2	Links between Items 1, 2
1	Babiloni, F.	Cherubino, P.	373
2	Cherubino, P.	Trettel, A.	256
3	Al-Nafjan, A.	Aldayel, M.	220
4	Cartocci, G.	Cherubino, P.	217
5	Aldayel, M.	Ykhlef, M.	201
6	Rossi, D.	Trettel, A.	122
7	Maglione, A.	Trettel, A.	95
8	Trettel, A.	Ykhlef, M.	24

4 DISCUSSION

Neuromarketing tools have emerged as valuable tools for researchers and practitioners in delving deeper into consumer behavior (e.g., emotion, attention, and preference) towards marketing stimuli such as advertising compared to others [35, 37, 45, 46]. These techniques have been widely applied in marketing studies to determine effective communication channels, such as television, radio, Facebook, Twitter, and others, for successful advertising [1, 47] and to uncover implicit gestures. The utilization of GSR, ET, ECG, EMG, and IAT offers several benefits in various research contexts. In consumer research, GSR is valuable for measuring emotional dimensions and autonomic nervous system activity. ET allows researchers to understand visual attention and gaze patterns, providing insights into user engagement and preferences. ECG enables the measurement of heart rate and heart rate variability, serving as a reliable indicator of emotional valence. EMG aids in assessing facial muscle activity, helping to analyze facial expressions and emotional responses. IAT explores implicit biases and attitudes towards different stimuli, contributing to a deeper understanding of subconscious associations. Overall, integrating these techniques enhances the ability to investigate emotional responses, cognitive processes, and implicit attitudes in diverse research domains.

In the ever-evolving world of marketing research, the allure of non-brain tools has sparked a fervent quest for a deeper comprehension of consumer behavior in the face of advertising stimuli. Embracing this thrilling pursuit, the present study embarked on a remarkable journey, guided by the PRISMA framework, to identify pertinent articles that utilized ET, GSR, EMG, ECG, and IAT tools within the realm of neuromarketing. With meticulous precision, fifty-one articles and seven review articles were selected from the WoS database. But the exploration didn't stop there. With the bibliometric analysis, the researchers embarked on a grand expedition into the global academic landscape. It was here that the prominent countries, distinguished

institutions, influential authors, prestigious journals, and captivating trend citations were brought to light, promising to revolutionize the course of future studies while saving valuable time for newbie scholars.

The bibliometric analysis revealed Spain as the most productive country, with thirteen documents and 155 TCs. Not far behind, the United States showcased its intellectual prowess with ten groundbreaking works and 44 trend citations. Amidst this scholarly trend, the Complutense University of Madrid took center stage with six publications. Other esteemed institutions, including BrainSigns SRL, King Saud University, and Universitat Politecnica De Valencia, showcased their brilliance with four documents each, earning trend citations of 116, 76, and 51, respectively. Even in the far reaches of academia, the intellectual flame burned bright as Imam Mohammad Ibn Saud Islamic University made its mark with two intriguing works. Frontiers in Psychology emerged as a top journal within the realm of scholarly journals, publishing eight enlightening articles and garnering 108 citations. Yet, Computational and Mathematical Methods in Medicine was the highest-cited journal. With one publication, it amassed 64 citations, a testament to its impact on the scholarly landscape. Amidst these contributions, Babiloni, F. and Cherubino, P. led the authors' list with four publications each and 116 citations. Followed by Trettel, A., Ykhlef, M., Al-Nafjan, A., Aldayel, M., Alsharif, A. H., Tur-vines, V., and Manas-Viniegra, L., who published three documents with 76, 76, 66, 66, 56, 35, 28 TCs, respectively. Although Maglione, AG. had published two documents, her documents have the highest citations with 104 TCs.

Within this sea of knowledge, "Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials" earned 64 citations and solidified its status as the most cited work, published in the prestigious Computational and Mathematical Methods in Medicine. Following closely, "Deep Learning for EEG-Based Preference Classification in Neuromarketing" made its mark in the scholarly realm, accumulating 54 citations with its publication in Applied Sciences-Basel as the second-highest cited article. As connections formed between authors, the study revealed that the strongest links between two references were 373 links between Babiloni, F. and Cherubino, P., followed by Cherubino, P. and Trettel, A. with 256 links between them. On the other hand, the links strength between Trettel, A. and Ykhlef, M. were 24 links, the weakest between the two authors. Furthermore, the study found "neuromarketing" as the most frequent word, with 26 occurrences and 82 TLS, followed by "consumer neuroscience", with 13 occurrences and 41 TLS.

In summary, the research revealed that emerging countries have yet to contribute significantly to neuromarketing. In light of this revelation, this paper calls upon scholars and researchers to contribute to marketing research; non-brain tools such as ET, GSR, EMG, ECG, and IAT have emerged as powerful allies, offering profound insights into consumer behavior and their responses to advertising stimuli. Guided by the esteemed PRISMA framework, the current study embarked on a thrilling quest, unearthing a treasure trove of fifty-one articles and seven reviews from the esteemed WOS database. But this was just the beginning.

5 CONCLUSIONS

In recent years, there has been a significant upsurge in the interest among marketers and advertisers to better understand customers' emotions. This growing interest has resulted in the adoption of non-brain tools (e.g., ET, GSR, EMG, ECG, and IAT

tools) to delve deeper into customers' emotional responses towards various marketing stimuli, including ads, brands, and products. These tools have proven to be reliable means of capturing and analyzing customers' emotional responses within the marketing environment, illuminating the connections between customers and their surrounding context in everyday life and uncovering their underlying emotional states, whether positive or negative. As a result, the findings have underscored the pivotal role of non-brain tools in capturing and recording emotional responses toward stimuli.

Despite the advancements in neuromarketing tools, their widespread implementation in the industrial sector remains somewhat limited. Further research is needed to explore the potential benefits and limitations of utilizing metabolic, electrical, and non-brain tools in marketing research and to investigate how these tools can be effectively integrated with traditional methods to attain a more comprehensive understanding of consumer decision-making processes. Such research endeavors can also delve into the implications of employing these tools for marketing strategies, including enhancing product design and improving advertising effectiveness. By conducting comprehensive investigations, marketers and researchers can gain valuable insights into the effectiveness of different marketing stimuli and their impact on consumers' emotions.

Overall, the utilization of non-brain tools in marketing research represents an intriguing and promising avenue for future exploration. It is hoped that there will be an increase in the availability of training courses for marketers and practitioners to gain the necessary skills and knowledge to effectively leverage this revolutionary field. This, in turn, can lead to improved marketing strategies, enhanced advertising campaign effectiveness, and reduced wasted budgets allocated to marketing strategies and advertising campaigns. Ultimately, integrating neuromarketing tools with traditional marketing research methods holds great potential for enhancing the understanding of consumer behavior and facilitating evidence-based decision-making in the marketing domain.

6 LIMITATIONS AND FUTURE DIRECTIONS

The paper aimed to minimize methodological restrictions in the study, but some restrictions were still encountered, and suggestions were made for future research. The study focused solely on articles published in English language journals between 2013 and 2023, which were indexed in the WoS database. This approach, however, ignored other documents, such as proceeding papers and editorials, which could lead to bias in the study. To address this limitation, the authors recommend that researchers and marketers from emerging countries publish their works in this field for future studies. The paper provides a comprehensive overview of using EMG, GSR, ECG, ET, and IAT tools in neuromarketing activities between 2013 and 2023, based on the analyzed publications.

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