



Current Trends in the Application of EEG in Neuromarketing: A Bibliometric Analysis

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Abstract

Despite several neuroscience tools existing, electroencephalography (EEG) is the most used and favoured tool among researchers because of its relatively low cost and high temporal resolution. Our study aimed to identify the global academic research trends of the empirical EEG studies in neuromarketing. This paper adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to identify relevant articles. A bibliometric analysis software (VOSviewer) was used to evaluate thirty open-access articles found in the Scopus database between 2016 and 2020. We found that the USA is the most productive country with five research articles that used the EEG tool in marketing studies, followed by Australia, Italy, and Malaysia with three articles each. According to the most prolific journals in neuromarketing, it has been found that *Frontiers in Neuroscience* journal (CiteScore 5.4) is the most prolific journal with two articles and 25 total citations, followed by *Scientific reports* (CiteScore 7.1) with two articles and eighteen total citations, which lead us to infer that the publications' number does not necessarily reflect the citations' number. The study provides a profound and comprehensive overview of academic research that used EEG in marketing research.

Keywords: bibliometric analysis; consumer behavior; EEG; neuromarketing; Scopus database.

JEL classification: M30; M31; M39; O3.

1. INTRODUCTION

In spite of the wide usage of self-report measures (i.e., interviews, surveys, and focus groups) in marketing research to understand the consumers' responses/reactions to marketing

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activities such as advertising [Cherubino et al. \(2019\)](#), it has failed down to provide precise information about the real behaviours of consumers toward marketing activities ([Jordao et al., 2017](#)). The increased application of neuroscientific methods such as the EEG in marketing activities encouraged the emergence of a new field of knowledge known as "neuromarketing" ([Stanton et al., 2017](#)). Neuromarketing is a multidisciplinary field that includes marketing, neuroscience, and psychology, defined as consumer neuroscience's commercial application ([Venkatraman et al., 2015](#)). Therefore, advertisers, researchers, and marketers have shifted to using neuroscience tools such as the EEG to measure and record consumers' hidden and unconscious responses, which cannot be measured by self-report methods ([Alsharif, Salleh, et al., 2021a](#)).

According to [Vlăsceanu \(2014\)](#), combining traditional marketing and neuromarketing methods can provide data and relevant insights about reactions of consumers. Obviously, neuroscience methods and techniques have a significant role in neuromarketing research. [Plassmann et al. \(2007\)](#) have divided neuromarketing methods into two groups: (a) Metabolic brain techniques, i.e., functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), and (b) Electrical brain techniques, i.e., electroencephalography (EEG) and magnetoencephalography (MEG). The previous study of [Alsharif, Salleh, et al. \(2021b\)](#), enabled identifying the EEG as the most used tool among researchers and scholars. The main aim of this study is to identify the current global research trends of the empirical EEG studies in the marketing activities, such as the leading countries, the most prolific academic institutions, the most productive authors, and journals.

According to the literature, the EEG tool was used for the first time to measure consumers' responses to the T.V. ads in the early 1970s ([Cherubino et al., 2019](#)). EEG is an electrical and non-invasive tool to measure the electrical activity of cortical regions of the brain by using several electrodes placed on the participant's head ([Berger, 1969](#)). [Kane et al. \(2017\)](#) emphasize that electrodes are endeavoured to measure small electrical signals in the brain's cortical regions by recording the voltage changes between two electrodes. EEG uses a 10-20 system ([Badcock et al., 2013](#)), which is a globally recognized method. This tool is used to place the electrodes on particular locations of the scalp of the volunteers, such as prefrontal (PF.), frontal (F), occipital (O), parietal (P), temporal (T), and central (C). According to [Silverman \(1965\)](#); [Rawnaque et al. \(2020\)](#); moreover, placed on the right and left parts of the head, EEG uses an equal number of electrodes.

EEG tool has excellent temporal resolution estimated in milliseconds (ms) and has poor spatial resolution estimated at 1 cm³ in the brain's cortical areas ([Burle et al., 2015](#); [Aditya & Sarno, 2018](#); [Bazzani et al., 2020](#)). It is also neither expensive nor noisy; besides, it is not suitable for recording the distal regions in the brain ([Morin, 2011](#)). Scientific literature indicates five frequency bands that this technique has (i.e., delta < 4Hz, theta from 4-7 Hz, alpha from 8-15 Hz, beta from 16-31 Hz, and gamma > 32Hz) ([Wei et al., 2018](#)). It is also used to record/measure attention, memory, and emotional valence ([Vecchiato & Babiloni, 2011](#); [Ohme & Matukin, 2012](#); [Di Flumeri et al., 2016](#)).

As the method is relatively new, emergent, and its usage in scientific research is still limited, current study concentrates on the global research trends of studies that used EEG in neuromarketing between 2016 and 2020; therefore, this paper tries to identify the global academic trends deeply to provide a comprehensive and concise retrospective of its usage. The main contributions of this bibliometric study can be envisioned as follow:

- The study presents an overview of annual and cumulative publications, besides the journal outputs from 2016 to 2020, which helps new scholars to know the global academic research trends in neuromarketing activities.
- The study provides vast and profound insights into the current EEG studies in the neuromarketing activities to be considered in the future studies.
- New directions for scholars who are interested into neuromarketing field are identified.

This study is organized as follows: [Section 2](#) provides the methods that have been used in the study. [Section 3](#) presents a bibliometric analysis of the relevant articles. [Section 4](#) discusses and summarises the findings of the relevant articles. [Section 5](#) is dedicated to the conclusion and implications. [Section 6](#) presents the limitation of the study and future agendas.

2. METHODS

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol in order to identify the relevant articles for this review ([Moher et al., 2015](#)). We have followed the bibliometric analysis to accomplish the aim of this study, thereby to know and identify the global research trends in neuromarketing research in terms of the most contributed countries and academic institutions, the leading journals/sources in this field such as the most contributed authors that published articles by using EEG in neuromarketing research, the most-cited articles, and the occurrences of the keyword to assess the improvement in the publications ([Alsharif, Salleh, et al., 2021a](#)). Scopus database was chosen as a basis for the study, as it is widely used by scholars and researchers to identify the development in the relevant field ([Słupińska et al., 2021](#)), additionally, it provides a significant bibliography dataset (e.g., countries, academic institutions, affiliations, references, publishers, citations, authors, etc.).

The VOSviewer software was applied in order to create visualization maps due to simplification of bibliometric research in several areas. For example, VOSviewer has been used in neuromarketing ([Alsharif, Salleh, Baharun, et al., 2021](#); [Sánchez-Fernández et al., 2021](#)), social media ([Abbas et al., 2021](#); [Abbas et al., 2022](#)). These applied procedures will give us a comprehensive insight and understanding of the development of using the EEG in neuromarketing research, including the productive countries, institutions, authors, and so forth.

Data has been collected from the Scopus database in November 2021. The key theme of this study was articles that have used EEG in marketing research; the following search was applied to the title, abstract, and keywords: TITLE-ABS-KEY ((((neuromarketing OR consumer neuroscience) AND ((electroencephalography OR eeg) OR (erp OR event-related AND potential))))) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016)) AND (LIMIT-TO (O.A. , "all")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT TO (LANGUAGE , "English")).

The procedure enabled identification of thirty open-access articles, released between 2016 and 2020. Authors focused on empirical articles that used EEG tool between 2016 and 2020 due to increase number of publications. In addition, it has only focused on English articles due to that English language was commonly used. We aimed to find as many articles as possible to explore and underly the academic global trends of using EEG research in

marketing activities. **Figure no. 1** shows the process of selecting articles for this study. The articles included into the study had to meet the following characteristics:

- Method: EEG
- Publication year: 2016 to 2020.
- Language: English.
- Document type: research article (reviews, conference papers, and editorials were excluded).

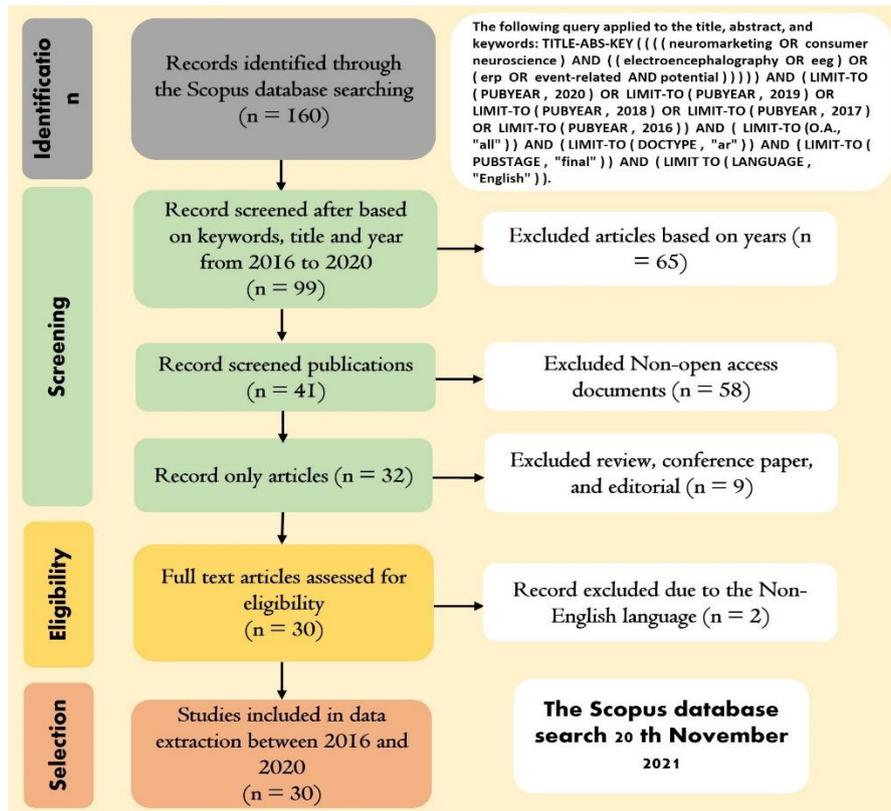


Figure no. 1 – PRISMA protocol to identify documents for this bibliometric study

3. RESULTS

After the procedure, 30 articles that used EEG in marketing research and published in an academic journal were identified. A remarkable growth in publication was detected, wherein more than 80% of total articles have been published in the last three years, 2018, 2019, and 2020. **Figure no. 2** shows the annual and cumulative publications published between 2016 and 2020. For example, two articles were published in 2016, while this number increased almost six times in 2020. According to the increased interest of researchers and practitioners in the neuromarketing field, the increasing number of publications and researchers interested in using the EEG in marketing research has expanded.

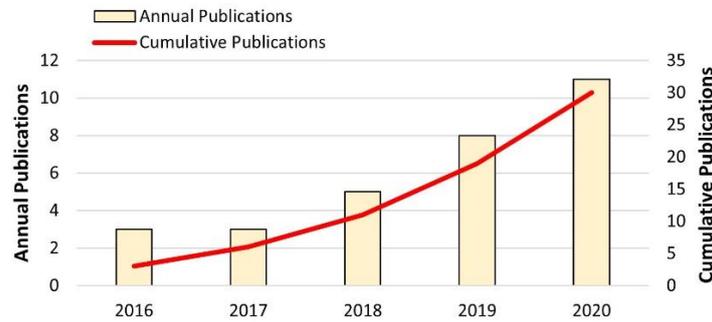


Figure no. 2 – The annual and cumulative publications used EEG in neuro-marketing between 2016 and 2020

3.1 A Bibliometric analysis

3.1.1 Productive countries and institutions

It has been noted that the most productive countries with at least two articles can be divided into three categories (i) countries have produced five articles; (ii) three countries have published three articles each; and (iii) three countries produced two articles each (Table no. 1). Table no. 1 illustrates that USA, Australia, Italy, and Malaysia have produced more than 50% of total articles since 2016. For example, the USA is the most productive country with five articles and the second-highest total citation (28 total citations), while its Harvard Medical School has published two articles with three citations. Although Malaysia has published three articles with twenty-three citations, its institute (Monash University Malaysia) has published the highest-cited article with twenty-six citations. Despite being in the tail of the list, the UK has contributed the highest-cited articles with thirty-two citations.

Table no. 1 – The most contributed countries and institutions in neuro-marketing research (minimum two articles contribution of the country)

Country	T.P. 2020	T.C. 2020	H-index	The most prolific academic institutions	T.P.i 2020	T.C.i 2020
USA	5	28	4	Harvard Medical School	2	3
Australia	3	25	3	University of Newcastle	1	21
Italy	3	19	2	Università Cattolica del Sacro Cuore	2	3
Malaysia	3	23	2	Monash Malaysia	1	26
Denmark	2	25	2	Neurons Inc	2	25
Spain	2	9	2	University of Seville	1	8
UK	2	32	2	Nottingham Trent University	1	16

Note: T.P.: total publication, T.C.: total citations, T.P.i: total publications by institution, T.C.i: total citation for institution

3.1.2 Most productive authors

Table no. 2 demonstrates the authors in neuromarketing research having the highest number of articles. The fifteen authors are affiliated with eight different academic institutions and seven countries with nineteen articles that refer to a high corporation. It has been observed

that four authors have contributed by two articles, and the rest authors have released one article respectively. For example, Ramsøy T.Z., affiliated to Neurons Inc and Copenhagen Business School (Denmark), is the most productive author with two articles and 25 total citations, followed by Balconi, M., Angioletti, L., and Sebastiani, R. who affiliated to Catholic University of the Sacred Heart (Italy) with two articles but only three total citations each. Although Cartocci G., Modica E., Babiloni, F., Goto N., and Schaefer A. have published only an article, their articles have been cited mostly: with 26 total citations each. Last but not least, Soria Morillo L.M. and Alvarez-Garcia, J.A. are affiliated with the University of Seville (Spain); they have produced an article with eight total citations each.

Table no. 2 – The most ten contributed authors in neuro-marketing research (min. article and seven citations)

Author's name	T.P.	T.C. 2020	Affiliation	Country
Ramsøy T.Z.	2	25	Neurons Inc	Denmark
Balconi, M.	2	3	Catholic University of the Sacred Heart	Italy
Angioletti, L.	2	3	Catholic University of the Sacred Heart	Italy
Sebastiani, R.	2	3	Catholic University of the Sacred Heart	Italy
Cartocci G.	1	26	Sapienza University of Rome	Italy
Modica E.	1	26	Sapienza University of Rome	Italy
Babiloni, F.	1	26	Sapienza Università di Roma	Italy
Goto N.	1	26	Monash Malaysia	Malaysia
Schaefer A.	1	26	Monash Malaysia	Malaysia
Skov M.	1	23	Copenhagen Business School	Denmark
Bosshard S.S.	1	21	University of Newcastle	Australia
Bourke J.D.	1	21	University of Newcastle	Australia
Koller M.	1	21	Vienna University of Economics and Business	Austria
Soria Morillo L.M.	1	8	University of Seville	Spain
Alvarez-Garcia, J.A.	1	8	University of Seville	Spain

3.1.3 Leading journals

Table no. 3 reveals that the ten most productive journals published articles that applied/used the EEG tool in neuromarketing. It has been noticed that four journals have published only two articles, and the rest of the journals have published an article each. Additionally, according to the CiteScore of Scopus database in 2020, three journals have higher than five CiteScore. For example, *Frontiers in Neuroscience* (CiteScore 5.4) is the most prolific journal with two articles and the highest total citations (25 citations), as well its published the highest cited article (23 citations) that was written by [Ramsøy et al. \(2018\)](#). This was followed by *Scientific Reports* journal (CiteScore 7.1) with two articles and the second-highest citation (18 total citations), which has published the third-highest cited article that was written by [Doborjeh et al. \(2018\)](#) with 16 citations. Although *Cogent Psychology* (CiteScore 1.4) ranked in 5th level in the list with an article, it published the second-highest cited article (21 citations), which belongs to [Bosshard et al. \(2016\)](#). It can be concluded that publications' number do not necessarily reflect the citations' number. Finally, *Frontier in Psychology* (CiteScore 3.5) has published an article with the least total citations.

Table no. 3 – The most ten productive journals with published articles that used EEG in neuromarketing research

Source/Journal	Cite Score 2020	T.P. 2020	T.C. 2020	Reference of the most cited document	Time cited	Publisher
Frontiers in Neuroscience	5.4	2	25	Ramsøy et al. (2018)	23	Frontiers Media Sa
Scientific Reports	7.1	2	18	Doborjeh et al. (2018)	16	Nature Research
International Journal of Advanced Computer Science and Applications	1.1	2	7	Teo et al. (2018)	6	Science and Information Organization
Frontiers in Human Neuroscience	5.1	2	4	Qiu et al. (2019)	3	Frontiers Media Sa
Cogent Psychology	1.4	1	21	Bosshard et al. (2016)	21	Taylor & Francis AS
Behavioral Sciences	3.4	1	4	Harris et al. (2019)	4	MDPI
Biological Psychology	3.4	1	16	Goto et al. (2017)	16	Elsevier
Sustainability	3.9	1	3	Balconi et al. (2019)	3	MDPI
Psychologia	0.2	1	2	Nittono and Watari (2017)	2	Psychologia Society
Frontier in Psychology	3.5	1	1	García-Madariaga et al. (2020)	1	Frontiers Media Sa

Note: TP; total publication, T.C.; total citations

Figure no. 3 displays the visualized snapshot of sources that have produced at least an article, wherein 30 articles were found that 22 journals have published.

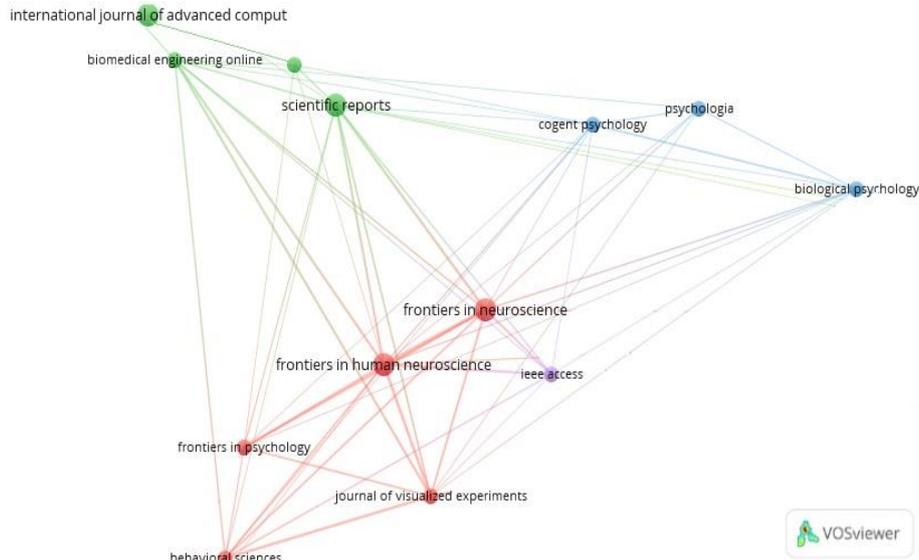


Figure no. 3 – Snapshot of sources that published at least one article in neuromarketing research

3.1.4 Analysis of Keywords

Keywords occurrences is considered as a quantitative approach that uses numbers to express the strength links between pair keywords in bibliometric analysis, which means a larger number indicates a stronger link (Ravikumar *et al.*, 2015; Wang & Chai, 2018); besides, it provides a comprehensive explanation of the articles' content. The link strength between a couple of keywords represents the frequency of these keywords in an article. The TNL refer to the overall number of appearances altogether in an article. It has set two as the minimum (min.) occurrences of author keywords in VOSviewer software. That means, the appearances of two keywords at least two times on the bibliometric map in an article. Author keywords co-occurrence analysis conducted in this paper, which involved 14 keywords from 30 articles in 22 sources with minimal two keyword occurrences. According to Comerio and Strozzi (2019), the analysis of co-occurrence keywords is important to present general claims about the content of the article. In addition, the method is effective for the evaluation and assessment of the trend themes in a particular subject, for example, neuromarketing, by checking the global and current trend of publication in a particular subject (Alsharif, Salleh, Baharun, *et al.*, 2021). Figure no. 4 shows that the EEG tool has been used to study, understand, and explore the consumer behaviours (such as emotion, attitudes, and attention) towards marketing stimuli (such as advertising).

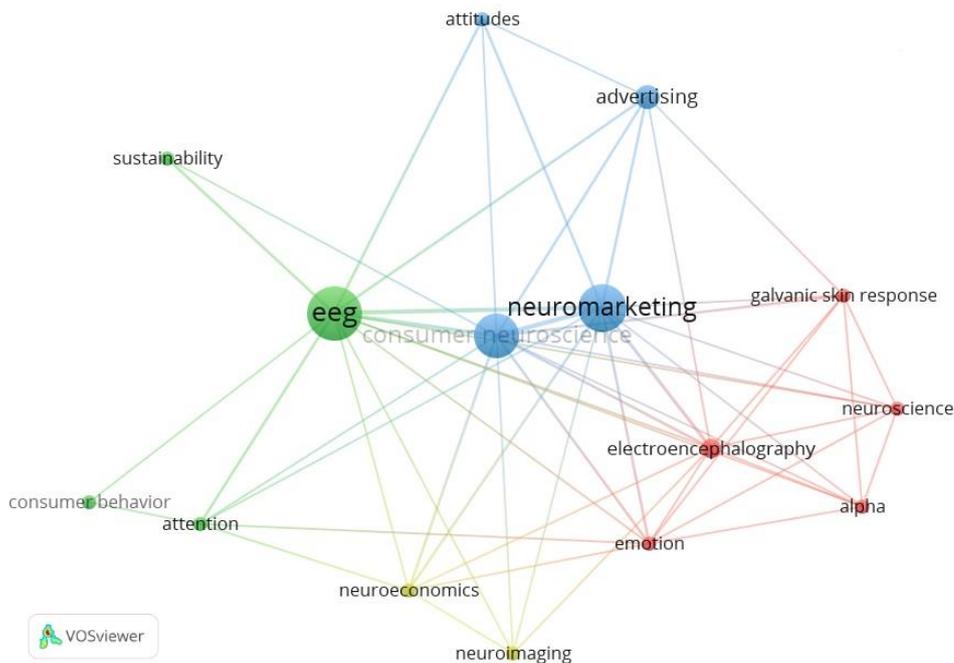


Figure no. 4 – Snapshot of authors' keywords co-occurrence (with min. 2 occurrences).

Table no. 4 summarizes the most recurrent keywords with a min. two of occurrences, wherein the electroencephalography (EEG) is the highest keyword occurrence, followed by

neuromarketing word. For example, electroencephalography (EEG) is the most occurrence word with 15 occurrences and 37 total link strength (T.L.S.). Neuromarketing used electroencephalography (EEG) tool to study, record, measure, understand and explore the consumer behaviour (2 occurrences, 2 T.L.S.), emotion (2 occurrences, 11 T.L.S.), attention (2 occurrences, 7 T.L.S.), and attitudes (2 occurrences, 6 T.L.S.) toward marketing stimuli such as advertising (4 occurrences, 9 T.L.S.).

Table no. 4 – Top keywords by the minimum of two occurrences.

#	Keyword	Occurrences	T.L.S
1	Electroencephalography (EEG)	15	37
2	Neuromarketing	10	27
3	Consumer neuroscience	9	26
4	Advertising	4	9
5	Emotion	2	11
6	Neuroeconomics	2	9
7	Galvanic skin response	2	8
8	Alpha	2	7
9	Attention	2	7
10	Neuroscience	2	7
11	Attitudes	2	6
12	Neuroimaging	2	5
13	Sustainability	2	3
14	Consumer behaviour	2	2

Note: T.L.S.: total link strength

3.1.5 Citation analysis

Citations analysis is significant to know the global trends of citations, giving valuable insights about the most-cited articles or documents in a specific research field such as neuromarketing. Therefore, it provides impactful articles to be considered in the future for new researchers or practitioners. We have reviewed and analysed the total citations (T.C.) of a total of 30 articles that used the EEG tool in neuromarketing research. [Table no. 5](#) shows the most-cited articles that have used EEG in the neuromarketing research to study and explore the consumer behaviour regarding marketing stimuli such as advertisings with more than 4 T.C. As it is shown in [Table no. 5](#), higher than 20 T.C. have been found in two articles. For example, the article titled "Frontal Brain Asymmetry and Willingness to Pay" is the highest-cited article (23 T.C.), written by [Ramsoy et al. \(2018\)](#) and published by *Frontiers in Neuroscience* journal. This was followed by the article "Established liked versus disliked brands: Brain activity, implicit associations and explicit responses" with 21 citations written by [Bosshard et al. \(2016\)](#) and produced by *Cogent Psychology* journal. Moreover, it has been noted that three articles have 16 citations each; besides, three articles have less than ten citations, wherein the title "Consumer neuroscience and digital/social media health/social cause advertisement effectiveness" has the least citations with 4 T.C.

Table no. 5 – The top articles on the Scopus database by citation score with minimum four total citations

Document Title	T.C. 2020	Reference	Journal
Frontal Brain Asymmetry and Willingness to Pay	23	Ramsøy <i>et al.</i> (2018)	Frontiers in Neuroscience
Established liked versus disliked brands: Brain activity, implicit associations and explicit responses	21	Bosshard <i>et al.</i> (2016)	Cogent Psychology
Neural signals of selective attention are modulated by subjective preferences and buying decisions in a virtual shopping task	16	Goto <i>et al.</i> (2017)	Biological Psychology
Electroencephalographic, heart rate, and galvanic skin response assessment for an advertising perception study: Application to antismoking public service announcements	16	Cartocci <i>et al.</i> (2017)	Journal of Visualized Experiments
Modelling Peri-Perceptual Brain Processes in a Deep Learning Spiking Neural Network Architecture	16	Doborjeh <i>et al.</i> (2018)	Scientific reports
Discrete classification technique applied to T.V. advertisements liking recognition system based on low-cost EEG headsets	8	Soria Morillo <i>et al.</i> (2016)	Biomedical engineering online
Classification of affective states via EEG and deep learning	7	Teo <i>et al.</i> (2018)	International Journal of Advanced Computer Science and Application
Consumer neuroscience and digital/social media health/social cause advertisement effectiveness	4	Harris <i>et al.</i> (2019)	Behavioral Sciences

3.1.5.1 Co-Citation analysis

Co-citation can help scholars to determine the literature's structure on a particular topic (Block & Fisch, 2020). It also enables researchers and practitioners to evaluate the topic's content, and it is an indicator of two references' appearance in one document. The VOSviewer tool was used to identify the links between two references by determining the link strength between both references, where the number of links between both references refers to the correlation strength between them (Van Eck & Waltman, 2013). The link strengths number between pair references is demonstrated in Table no. 6, wherein a larger number means larger links between two references. We also found that the strongest links between two references were seven links between Cartocci *et al.* (2017) and Harris *et al.* (2019), followed by Ramsøy *et al.* (2018) and Ramsøy *et al.* (2019) with five links between them. The links between Bosshard *et al.* (2016) and Goto *et al.* (2017) were four links, while the links strength between Harris *et al.* (2019) and Soria Morillo *et al.* (2016) were three links. The rest references had only two links between them.

Table no. 6 – The top empirical article pairs with more than two TLS (minimum citations of document 5)

#	Author 1	Author 2	Links between Authors 1, 2
1	Cartocci <i>et al.</i> (2017)	Harris <i>et al.</i> (2019)	7
2	Ramsøy <i>et al.</i> (2018)	Ramsøy <i>et al.</i> (2019)	5
3	Bosshard <i>et al.</i> (2016)	Goto <i>et al.</i> (2017)	4
4	Harris <i>et al.</i> (2019)	Soria Morillo <i>et al.</i> (2016)	3

#	Author 1	Author 2	Links between Authors 1, 2
5	Soria Morillo <i>et al.</i> (2016)	Teo <i>et al.</i> (2018)	2
6	Goto <i>et al.</i> (2017)	Ramsøy <i>et al.</i> (2018)	2
7	Balconi <i>et al.</i> (2019)	Cartocci <i>et al.</i> (2017)	2
8	Qiu <i>et al.</i> (2019)	Soria Morillo <i>et al.</i> (2016)	2

3.1.5.2 Co-Citation network

This paper used VOSviewer software for the co-citation network analysis. The instructions and guidance of Baker *et al.* (2020) have been followed to visualize the co-citation network of the top eight articles with min., two T.L.S. and five citations in a map. The paper findings revealed the four groups/sets with large correlations between them, as depicted in Figure no. 5. The red set is the largest set, which was led by Ramsøy *et al.* (2018). The green set was dominated by Cartocci *et al.* (2017). Doborjeh *et al.* (2018) dominated the blue set, while the yellow set was dominated by Soria Morillo *et al.* (2016). Although these sets dealt with different aspects of neuromarketing activities, these sets were positively interrelated.

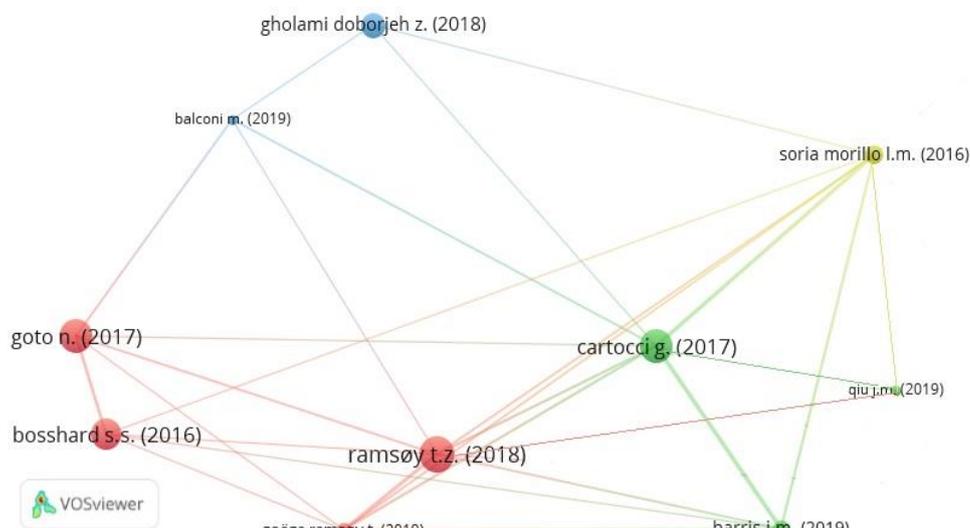


Figure no. 5 – Map of pair documents between authors 1 & 2 (with minimum of two links and five citations)

3.2 Summary of the selected articles

After extracting the relevant papers from the Scopus database, it has found thirty articles for this study. Table no. 7 summarizes the articles involved in this study, providing research objectives, methods used, and the main findings obtained.

Table no. 7 – Summary of relevant articles for this study.

Reference	Title	Objectives	Method	Context	Findings
<i>Bosshard et al. (2016)</i>	Established liked versus disliked brands: Brain activity, implicit associations and explicit responses	To investigate the implicit and explicit attitudes of consumers toward brands.	EEG, Self-report, IAT	24 participants	The study found that preferred brands reflect more motivational aspects and activity signals in the right parietal cortices than unpreferred brands.
<i>Chew et al. (2016)</i>	Aesthetic preference recognition of 3D shapes using EEG.	Identifying the process and approach to recognizing individuals' aesthetic preference for 3D shapes.	EEG	5 participants	The rhythms from frontal channels Fz, F3, and F4 are suitable for identifying human preference (e.g., like and dislike) toward moving 3D shapes.
<i>Soria Morillo et al. (2016)</i>	Discrete classification technique applied to T.V. advertisements liking recognition system based on low-cost EEG. headsets	To investigate how consumers' brain responds to advertisement's scene by using discrete classification techniques.	EEG	10 participants	The findings revealed that the discrete classification techniques have increased the percentage of accuracy, reaching 75%, and the time-consuming algorithm was declined by almost 30%.
<i>Cartocci et al. (2017)</i>	Electroencephalographic, heart rate, and galvanic skin response assessment for an advertising perception study: Application to antismoking public service announcements	To estimate the accurate measurement of the cerebral and emotional perception of social advertising.	GSR, ECG, EEG	22 participants	The antismoking campaign characterized by a symbolic communication style has gained the highest approach values, as evaluated by the approach-withdrawal index. At the same time, an image based on the "fear arousing appeal" and with a narrative style reported the highest and lowest effort values index, respectively.
<i>Goto et al. (2017)</i>	Neural signals of selective attention are modulated by subjective preferences and buying decisions in a virtual shopping task	Investigating whether the famous neural markers of selective attention were modified by differences in subjective preference to products.	EEG/ERP	38 participants	The variations in subjective preferences toward goods have strongly modulated PSW and LPP by subsequent purchasing decisions. Therefore, Late positive potential and Positive slow waves could reflect cognitive processes (e.g., selective attention).

Reference	Title	Objectives	Method	Context	Findings
Guixeres et al. (2017)	Consumer neuroscience-based metrics predict recall, liking and viewing rates in online advertising	To investigate the effectiveness of ad (e.g., liking ad) and the number of views on YouTube channels.	ECG., ET, EEG, Survey	35 participants	The strong relationship between neuroscience metrics and self-reported of ad effectiveness (e.g., liking ad), and the number of views on YouTube.
Ma et al. (2018)	You win, you buy- How continuous win effect influence consumers' price perception: An ERP study	Examining whether the emotional arousal will influence the price perceptions; thereby, the purchase decisions of the participant.	ERP/EEG	23 participants	Participants' emotions highly influenced the participants' price perception (win/lose experience). Continuous/single wins produced more positive emotions than continuous/single losses. At the same time, it has noticed that more intense emotion produced in continuous wins/losses than single win/lose.
Ramsoy et al. (2018)	Frontal brain asymmetry and willingness to pay	Exploring and examining the potential role of the prefrontal asymmetry in calculating willingness to pay.	EEG	16 participants	The subsequent of willing to pay (WTP) responses were related to as asymmetry in the prefrontal cortex (PFC) in the gamma and beta band, additionally, the WTP decision/response was strongly related to gamma band..
Teo et al. (2018)	Classification of affective states via EEG and deep learning	To investigate the preferences and excitement of consumers toward three-dimensional visual stimuli.	EEG	16 participants	Deep learning approach has increased the accuracy of the emotion classification (e.g., preferences and excitement) between 13% and 18%, wherein it is almost reached 96%
Wei et al. (2018)	Using support vector machine on EEG for advertisement impact assessment	evaluating advertisement influence and the potential of consumers buying the advertised product.	EEG and Questionnaire	30 participants	The percentage of purchasing power was relatively high after watching the advertising.
Yang et al. (2018)	Characteristics of human brain activity during the evaluation of service-to-service brand extension	To identify the neural correlates of cognitive processes underlying the assessment of service-to-service (S-to-S) brand extension, and to develop a method of grouping	EEG/ERP	37 participants	It can elicit higher positive amplitude in P300 by low-fit stimuli. While mid and high-fit stimuli elicited higher negative amplitude at N400. Whereas low, mid, and

Reference	Title	Objectives	Method	Context	Findings
		stimuli to find the suitable degree of consumer's response toward a S-to-S brand extension.			high-fit did not show any significant difference at N2. The cognitive neural activity might differ between S-to-S brand extension and group to group (G-to-G) brand extension.
Balconi <i>et al.</i> (2019)	A neuroscientific approach to explore consumers' intentions towards sustainability within the luxury fashion industry	To investigate the consumers' expectations and the unspoken relevant to luxury consumers' implicit intention toward sustainable luxury products.	EEG/ERP	16 participants	The findings revealed an increase level of consumers' knowledge toward sustainable luxury products, besides observing more activity in the delta band.
Goto <i>et al.</i> (2019)	Can brain waves really tell if a product will be purchased? Inferring consumer preferences from single-item brain potentials	Examining if single-item ERPs could predict the consumer's preference for a specific product accurately and reliability.	EEG/ERP	40 participants	The accuracy of prediction toward consumers' preference for specific products is almost 70.8% using SI-ERPs, and also the accuracy varies based on ERPs type. LPP and PSW were better than N200 in predicting consumer's preferences. In addition, group-related ERPs could differentiate between high preferred and less preferred significantly.
Harris <i>et al.</i> (2019)	Consumer neuroscience and digital/social media health/social cause advertisement effectiveness	Developing and evaluating the effectiveness of action/emotion-based public health and social cause advertisements through the use of consumer neuroscience (e.g., cognitive neuroscience and affective neuroscience).	EEG and online survey	40 participants	Emotion-based advertisements are more effective than rational-based advertisements, thereby, leading to positive change in decision-making, increasing donation, and more liking.
Muñoz <i>et al.</i> (2019)	Selling of products: The use of single-electrode wireless EEG in consumer behaviour	Conducting an experiment to compare three sales approaches such as training approach/technique, traditional sale (unstructured approach), and structured approach by	EEG	92 participants	The findings revealed a concrete statistical difference in achieved sustained attention levels, wherein the findings revealed more levels in participants who were exposed to the sales training technique and over in

Reference	Title	Objectives	Method	Context	Findings
		using EEG to identify which sale technique was more effective to sustain attention levels of consumers			those who were exposed to one of those techniques which used by the neuroscience of consumption
Qiu <i>et al.</i> (2019)	Assessing feedback response with a wearable electroencephalography system		EEG/ERP	17 participants	The findings revealed that significant differences in the P3 and N2 components between positive, neutral, and negative feedback responses.
Ramsay <i>et al.</i> (2019)	A consumer neuroscience study of conscious and subconscious destination preference	To investigate the direct influence of emotional and cognitive responses of customers on preference destination that determined subsequent.	EEG	32 participants	The findings revealed that the arousal and cognitive load were highly connected to subsequently stated travel preferences; besides, consumers' subconscious emotional and cognitive responses are not identical to subjective travel preference.
Yang and Kim (2019)	Group-level neural responses to the service-to-service brand extension	To investigate the consumers' neural processes related to the judgment of S-to-S brand extension and propose the new stimulus to find appropriate and inappropriate S-to-S brand extension.	EEG/ERP	19 participants	the neural processes engaged in evaluating the S-to-S brand extension may be involved in evaluating the G-to-G brand extension. In addition, the left frontoparietal P3 might provide neural evidence for the acceptability of a new S2S brand extension.
Ma <i>et al.</i> (2019)	The influence of the consumer ethnocentrism and cultural familiarity on brand preference: Evidence of event-related potential	Exploring the influence of ethnic affiliation (e.g., Black African and Chinese people) on brand preference.	EEG/ERP	40 participants	The logo of the brand has highly influenced the Chinese participants' preference toward brands.
Biercewicz <i>et al.</i> (2020)	Method for selecting an engagement index for a specific type of game using cognitive neuroscience	To identify the most suitable engagement indices (six indices) by using EEG tool to determine whether a consumer-like arcade games.	EEG, Questionnaire	31 participants	The findings revealed that the optimal indicator is index 2 (theta/alpha), because it appropriately represents the opinion of the respondents, besides a strong indicator of enjoyment for some types of games.

Reference	Title	Objectives	Method	Context	Findings
Constantin <i>et al.</i> (2020)	EEG object recognition: Studies for criminal investigation and neuro-applications in social care	To design a model that can provide informed expectations of what consumers see online at a certain moment.	EEG	4 participants	The findings revealed that the accurate predictions of online and offline were 100% (for a set of colours) and 83.3 % (for a set of scenes), respectively.
Eijlers <i>et al.</i> (2020)	Measuring Neural Arousal for Advertisements and Its Relationship With Advertising Success	To estimate how arousal is represented in the consumers' brain, then to measure consumer's arousal toward ads, thereby estimate the relationship between consumers' arousal and ad effectiveness	EEG	31 participants	The findings revealed that arousal is positively connected to prominent ads in the population and negatively to consumer attitudes toward particular ads.
García-Madariaga <i>et al.</i> (2020)	Revealing Unconscious Consumer Reactions to Advertisements That Include Visual Metaphors: A Neurophysiological Experiment	To investigate the consumers' responses toward print ads.	EEG., ET, GSR	43 participants	They found that ads with metaphors induce positive reactions/responses more than ads with non-metaphors, it has also found a favourable relation between cognitive load and conceptual complexity.
Kim <i>et al.</i> (2020)	The Impact of Visual Art and High Affective Arousal on Heuristic Decision-Making in Consumers	To identify the effect of visual art (e.g., Mondrian's and Kandinsky's artworks) on consumers' preferences.	EEG	38 participants	The findings showed that the visual effects had induced high emotional arousal, promoting heuristic decision-making.
Mengual-Recuerda <i>et al.</i> (2020)	Neuromarketing in haute cuisine gastronomic experiences	To analyse the influence of gastronomic experience on the consumers in a Michelin starred restaurant.	EEG, GSR/EDA, ET, In-depth interview	60 participants	found that food served by a chef positively influences emotions, while dishes with special presentations have more attention than traditional dishes
Moya <i>et al.</i> (2020)	What Can Neuromarketing Tell Us about Food Packaging	To investigate whether EEG, GSR, and ET can provide valuable information about the influence of food packaging on consumers' attention and purchase decisions.	EEG, GSR, ET, focus group	43 participants	The findings illustrated that neuromarketing tools such as EEG, GSR, and ET could provide brands with valuable information about the packaging design of foods.
Sargent <i>et al.</i> (2020)	Neuroergonomic Assessment of Hot Beverage Preparation and Consumption: An EEG and EDA Study	To investigate the correlational between the body activity and brain activity in daily habits, for example, hot beverage	EEG, EDA	26 participants	The findings illustrated that the market hot drinks machine was more efficient according to self-reports and

Reference	Title	Objectives	Method	Context	Findings
		preparation and consumption in an office environment.			behavioural performance measures, which was supported by EEG and EDA results; for example, during hot drinks preparation and consumption, has noted significant differences in arousal and valence metrics.
Stone <i>et al.</i> (2020)	Evaluations of commercial sleep technologies for objective monitoring during routine sleeping conditions	To estimate the accuracy of numerous commercial sleep technologies during in-home sleeping conditions.	EEG	5 participants	The study found that commercial sleep technologies presented less error and bias during sleep/awake states compared to sleep staging periods.
Williams <i>et al.</i> (2020)	A validation of Emotiv EPOC Flex saline for EEG and ERP research	To identify whether the Emotiv EPOC Saline Flex was capable of capturing the quality data of research.	EEG/EPR	20 participants	The study illustrated that the Emotiv EPOC Saline Flex could provide high-quality data of consumers' responses.
Zamani and Naieni (2020)	Best Feature Extraction and Classification Algorithms for EEG Signals in Neuromarketing	To investigate if the Support Vector Machine (SVM) can provide more accuracy for data classification toward brain activity.	EEG	32 participants	The study illustrated that the accuracy of the SVM algorithm for data classification almost more than 87% for the whole lobe and 84% for parietal lobe (PL) data

Note: SI-ERPs: Single-item ERPs; 3D: Three-dimensions; PFC: Prefrontal cortex; S-to-S: Service to service; G-to-G: Goods to goods; N: Negative polarity; P: Positive polarity; PSAs: Public service announcements; SVM: Support vector machine; WTP: Willingness to pay; PL: Parietal lobe.

4. DISCUSSION

In the last five years, it has been noted that there is a growing interest in using the neuroscience tools such as the EEG tool in marketing studies to better understand consumer behaviour regarding such marketing stimuli as advertising. Therefore, this study has applied the PRISMA framework to find the relevant articles that have used the EEG tool in studying consumers' behaviours in the neuromarketing field. Finally, after all the procedures, thirty articles were extracted from the Scopus database. In addition, this study has used the bibliometric analysis to provide the global academic research trends in neuromarketing activities, which helped to identify the most productive countries, academic institutions, authors, sources, and trend citations of articles to be considered in future studies and save researchers' time. For example, the USA was found to be the most productive country with five articles that used the EEG tool in marketing studies, followed by Australia, Italy, and Malaysia.

Although Malaysia is in the 3rd level list, the article with the highest number of citations was published by its institute (Monash University Malaysia). It has also been found that Ramsøy T.Z. is the most productive author with two articles and 25 T.C., followed by Balconi,

M., Angioletti, L., and Sebastiani, R. with two articles and three citations each. According to the most prolific journals in neuromarketing, it has been found that *Frontiers in Neuroscience* journal (CiteScore 5.4) is the most prolific journal with two articles and 25 T.C., followed by *Scientific reports* (CiteScore 7.1) with two articles and eighteen total citations, which lead us to infer that the publications' number does not necessarily reflect the citations' number. The article titled "Frontal Brain Asymmetry and Willingness to Pay" written by [Ramsoy *et al.* \(2018\)](#) and published by *Frontiers in Neuroscience* journal was found to be the most cited article with 23 citations; followed by "Established liked versus disliked brands: Brain activity, implicit associations, and explicit responses" with the second-highest citation count (21 citations), published in *Cogent Psychology* and written by [Bosshard *et al.* \(2016\)](#). The strongest link between the two references was detected between [Cartocci *et al.* \(2017\)](#) and [Harris *et al.* \(2019\)](#), with 7 links.

To recapitulate, it has been noted that the emerging countries do not contribute by articles in neuromarketing research. Therefore, this paper encourage scholars/ researchers from emerging countries to explore the global academic trends in neuromarketing studies, which can provide comprehensive information about the studies that can be considered in future research.

5. CONCLUSIONS AND IMPLICATIONS

Despite using self-report (i.e., interviews, surveys, and focus groups) in marketing research to understand the consumer responses/reactions to marketing activities such as (but not limited to) advertising practices, self-reports could not provide precise information on consumers' subconscious behaviours toward marketing activities. Therefore, advertisers, researchers, and marketers have shifted to using tools adapted from neuroscience such as the EEG to measure and record consumers' hidden and unconscious responses, which self-report-based methods are not able to measure. The growing interest of researchers in using neuroscience tools such as EEG in marketing studies to better understand consumer behaviour such as decision-making has increased the number of academic publications from two articles in 2016 to eleven articles in 2020. Therefore, this study aimed to provide an overview of the global trends in academic research in the field of neuromarketing (e.g., the most productive country, academic institutions, sources, authors, the most-cited articles, and the number of citations) that have used EEG in marketing studies as being less expensive, excellent temporal resolution, and less noisy.

The study has reviewed and analysed thirty articles that used EEG in marketing research. After a thorough analysis of the articles, it can be emphasized that developed countries are leading in the amount of articles published: the USA is the most productive country with five articles that used the EEG tool in marketing studies, followed by Australia, Italy, and Malaysia. It has also been found that the highest number of articles by author is two. [Ramsoy T.Z.](#) was found to be the most productive author with two articles and 25 citations. According to the most prolific journals in neuromarketing, it has been found that *Frontiers in Neuroscience* journal (CiteScore 5.4) is the most prolific journal with two articles and 23 total citations, followed by *Scientific reports* (CiteScore 7.1) with two articles and eighteen total citations, which lead us to infer that the publications' number does not necessarily reflect the citations' number. Article title "Frontal Brain Asymmetry and Willingness to Pay" is the most-cited article with 23 T.C., followed by "Established liked versus disliked brands: Brain

activity, implicit associations, and explicit responses" with the second-highest citation (21 citations). The strongest link between the two references was found between [Cartocci et al. \(2017\)](#) and [Harris et al. \(2019\)](#) with seven links.

6. LIMITATIONS AND FUTURE AGENDAS

This paper has tried to minimize the limitations in methodology; however, some limitations have occurred and provided several directions for the further research. In this research, it has been concentrated on the English articles that were published in open-access journals from 2016-2020 and were listed in the Scopus database. Therefore, this paper overlooked non-English articles, non-open-access articles, and other documents such as books, review papers, conference, and so forth. Thus, this paper is not free of bias. We encourage researchers and marketers from emerging countries to enter this embryonic field and leave their footprint by publishing articles for future works. We believe that this paper provides a profound overview of EEG studies in neuromarketing activities from 2016 to 2020.

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