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Article

Neuromarketing research in the last five years: A bibliometric analysis

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MARKETING | REVIEW ARTICLE

Neuromarketing research in the last five years: a bibliometric analysis

Ahmed H. Alsharif¹, Nor Zafir Md Salleh¹, Rohaizat Baharun¹ and Alharthi Rami Hashem E^{1,2*}

Abstract: Neuromarketing (NM) is an application of neuroimaging and physiological tools to record the neural correlates of consumers' behaviour (e.g., decision-making, emotion, attention, and memory) toward marketing stimuli such as brands and advertisements. This study aims to present the current tools employed in the empirical research in the last five years. In this article, we have followed the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) framework and a bibliometric analysis to select empirical and review papers that used NM tools in the last five years. We have extracted and analysed twenty-four documents from the Scopus database to answer our study questions. We found that electroencephalography (EEG) is the most popular neuroimaging tool in neuromarketing research, wherein has been used almost thirteen times. Followed by eye-tracking (ET) and galvanic skin response (GSR) as the most physiological tools, wherein have been applied almost four times for each tool. We hope that this study provides valuable insights into the common NM tools used in marketing research.

Subjects: Marketing; Marketing Research; Consumer Behaviour

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Ahmed H. Alsharif is a PhD student of Azman Hashim International Business School (AHIBS) at Universiti Teknologi Malaysia, Malaysia. His main research interests are neuromarketing, consumer behaviour, advertising, emotional and cognitive processes. He has published several research papers in the field of neuromarketing and consumer behaviour.

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PUBLIC INTEREST STATEMENT

The rising interest in exploring the neural and physiological reactions of consumers toward marketing stimuli such as advertisements and brands paid scholars and practitioners to employ physiological (e.g., ET, EMG, GSR, ECG) and neurophysiological (e.g., fMRI, EEG, ERP) tools in marketing research to explore, understand, analyze, explain, and predict the consumer's behaviour such as decision-making, the emotional (e.g., emotion) and cognitive (e.g., attention and memory) processes toward marketing stimuli. This study provides the global research trend in the neuromarketing field according to the outputs of publications such as the most productive countries, academic institutions, journals, authors, number of publications and citations.

Keywords: Neuromarketing; bibliometric analysis; physiological tools; neuroimaging tools

1. Introduction

Techniques and methodologies are highly important in the hyper-competitive environment, this has prompted companies to seek new effective methods to better understanding and predicting consumer behaviour. Thus, scholars have investigated how marketing research can benefit from these techniques to develop marketing practices and advertising research. Wherein, the fMRI investigation showed that most of the consumers' behaviour and decision-making are made beyond awareness that highly contributed to the purchase decisions (Agarwal & Dutta, 2015; Alsharif, Salleh, Baharun, & Effandi, 2021; Brierley, 2017). That study was a threshold for a new approach of studying consumer behaviour by using neuroscience technology in business research, which has called "neuromarketing". NM is located on the borderline between marketing, neuroscience, and psychology (Alsharif et al., 2021a; Alvino et al., 2020).

Traditional research methods were largely used self-report (e.g., surveys, focus groups) to study the responses of consumers (e.g., decision-making) toward marketing stimuli such as advertisements and brands (J. Harris et al., 2018). Self-report relies on the consciousness of the consumer behaviour and overlooks the unconscious; thereby, mismatching between what consumer says and does. Therefore, traditional research methods provide inaccurate and unreliable information about consumer's behaviour (Alsharif et al., 2021b; Alsharif, Salleh, Baharun, & Effandi, 2021), which has led to infer that most products and ads have failed in the first year (Jordao et al., 2017; Vecchiato et al., 2015). Accordingly, the majority of consumer's behaviour (e.g., decision-making, perception) occurs unconsciously, which is not possible for predicting by traditional research methods (Alsharif, Salleh, Baharun, Hashem, et al., 2021; Alsharif, Salleh, Baharun, & Effandi, 2021).

According to Ramsay (Ramsay, 2015), NM tools have been divided into four categories: (i) neuroimaging tools such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG), magnetoencephalography (MEG), steady-state topography (SST), functional near-infrared spectroscopy (fNIRS), and single photon emission tomography (SPET); (ii) Physiological techniques such as the electrocardiogram (ECG), eye-tracking (ET), electromyography (EMG), galvanic skin response (GSR) (Isabella et al., 2015); (iii) Self-report such as questionnaires, interviews, and focus groups; (iv) behavioural measurement such as implicit association test (IAT). For instance, physiological tools can record the physiological functions of consumers (e.g., breathing, heartbeat, pupil dilation, saccade, fixation, eye movements, sweating, and facial muscle movements) during exposure to advertisements (Hamelin et al., 2017). Meanwhile, neuroimaging tools enable to record of the dimensions of emotion, attention, and memory toward ads (Alsharif, Salleh, Baharun, Hashem, et al., 2021; Cherubino et al., 2019). According to the literature, EEG and fMRI are the most popular neuroimaging tools in NM research (Alsharif, Salleh, Baharun, Hashem, et al., 2021; Alsharif, Salleh, Baharun, & Safaei, 2020), meanwhile, ET is the most popular physiological tool.

The main goal of NM is a better understanding of the neural correlates of emotion, attention, memory, and decision-making in advertising campaigns (Alsharif, Salleh, Baharun, Hashem E et al., 2021; Alvino, 2019).

Therefore, NM has enormously received attention from an academic and industrial environment to employ these tools in consumer research to study concealed consumer reactions such as emotional and cognitive responses toward marketing stimuli (Hamelin et al., 2017). From an academic perspective, the publications number of NM has been remarkably increased since the last decade (Alsharif, Salleh, & Baharun, 2020). From an industrial perspective, the number of NM companies (e.g., Millward, Emsense) has been increased (Rawnaque et al., 2020). Consequently, NM research has attracted companies and scholars to use NM tools in their research to overcome

the limitations/restrictions of the orthodox methods and solving the marketing issues (Alsharif, Salleh, Baharun, & Safaei, 2020; Morin, 2011; Sebastian, 2014). Consequently, the contribution of neuroscientific methods became significant to enrich research about consumer behaviour in a new millennium of marketing that led several authors to speak about the benefits of NM (Lee et al., 2017; Ramsay, 2015; Songsamoe et al., 2019).

Several studies provide an overview of the most popular NM techniques which can be used in marketing research, for example, fMRI. However, there is a lack of investigation in NM studies that were employed physiological and neuroimaging techniques in the last five years to guide scholars and practitioners. Hence, the current study presents the current trend of NM research and the most NM tools (e.g., physiological and neurophysiological) used in marketing research in the last five years. We reviewed the literature to address the following research questions:

RQ1: What are the most-cited articles in the neuromarketing domain between 2004 and 2019?

RQ2: What are the most productive countries and authors in the neuromarketing domain between 2004 and 2019?

RQ3: What are the studies that employed neuromarketing tools in the last five years?

Answering these questions will give us a comprehensive knowledge of the current tools and studies employed in empirical NM research. To this end, this study seeks to combine as many directions as possible, besides, common research subjects are investigated deeply based on sub-domains to accomplish a precise, concrete, and concise conclusion. The key contributions of the current study are summarized as follow.

- The first study has reviewed, analysed, and discussed the latest studies that used neuromarketing tools in empirical research between 2015 and 2019.
- The first bibliometric analysis that shed light on the most trend global contributions in the neuromarketing field from 2004 to 2019.

In this vein, this study paper provides the methodology and data collection techniques in section 2. Section 3, presents the analysis of bibliometric, the studies used physiological and neurophysiological tools used in marketing research. Sections 4 and 5 present the discussion and conclusion of the study.

2. Methods

To answer the RQ1, RQ2, bibliometric analysis has been used in the current study to understand the global trends in NM, a bibliometric analysis provides the global trends such as the most productive journals, authors, countries and academics/institutions, and the most-cited articles in relevant topics based on the outputs of the publication from 2004 to 2019. To answer the RQ3, we have followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework recommended by Moher, et al. (Moher et al., 2015) to select empirical articles that used neurophysiological and physiological tools in marketing research in the last five years. The current study is characterized by extracting articles from the Scopus database relevant to our study. However, we also followed instructions recommended by Block and Fisch (Block & Fisch, 2020) to present an impactful bibliometric analysis and assess the structure of a particular research area. This process will help us to better understand the advancement of the NM field. We first have used the following query “neuromarketing” to select relevant articles from the Scopus database. Figure 1 shows the accumulative and annual publications in the NM domain from 2004 to 2019. We found 479 publications based on abstract, title, and keywords.

Figure 1. The number of publications in the neuromarketing research.

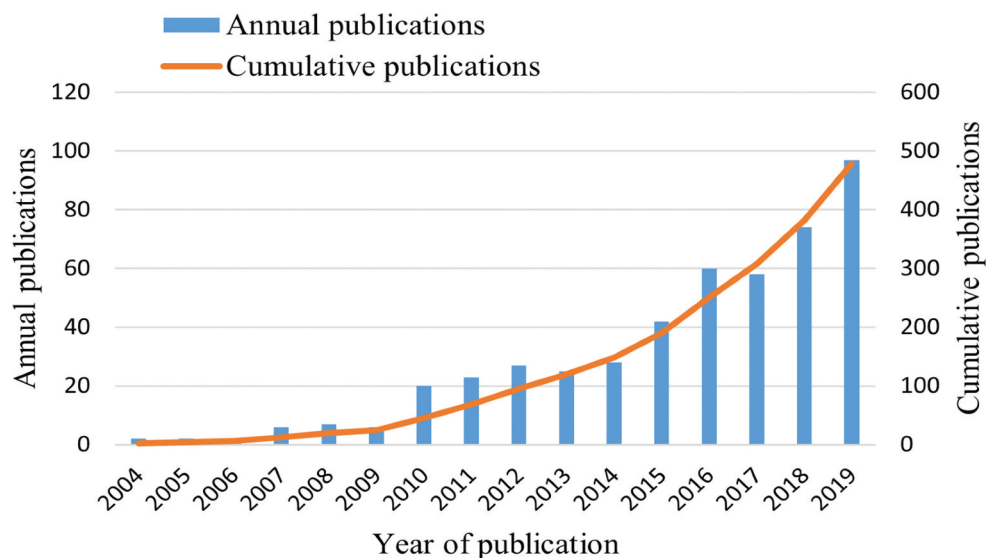
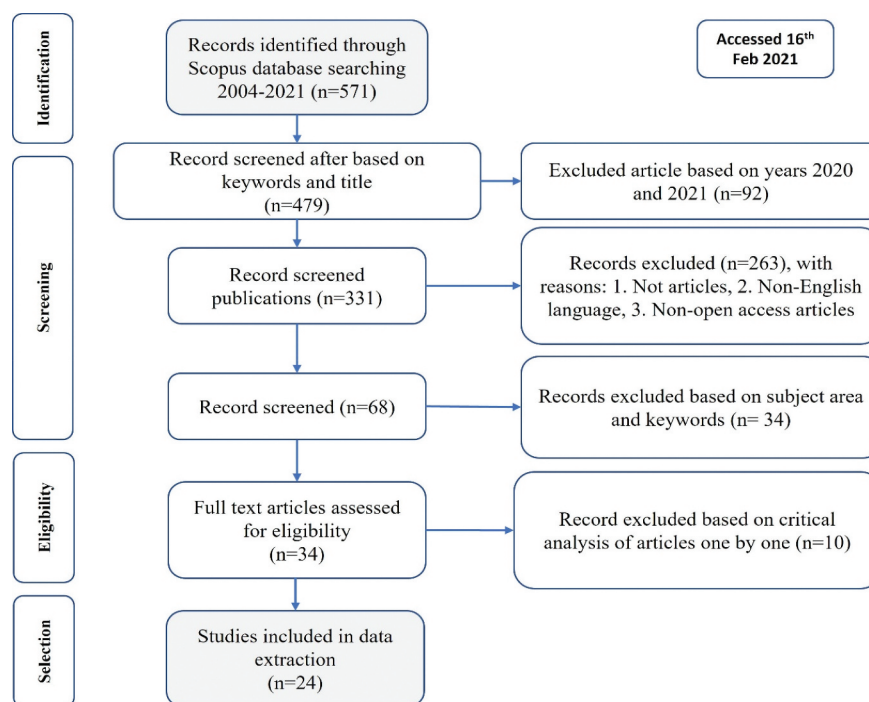


Figure 2. PRISMA Flow chart.



As depicted in Figure 2, we followed the PRISMA framework, which includes four stages: (i) identification as recording identified through database searching, (ii) screening the record documents, (iii) eligibility documents, and (iv) selecting studies, as follows:

- Empirical articles published between 2015 and 2019 were included.
- We excluded any other documents (e.g., conference papers, reviews) were excluded.
- We excluded any publications in the non-English language.

A total of thirty-four documents were extracted and after reviewed documents one by one, ten documents were excluded; therefore, a total of twenty-four documents were selected for this study based on the article questions. According to literature, the first article in NM was carried out in 2003 and published in 2004 by McClure, et al. (McClure et al., 2004). In addition, we have classified the selected documents based on the tool that used in the study, which includes three categories as tabulated in Table 1.

Table 1. Classification of neuromarketing tools in selected articles

Category	Device	Author's name
Neuroimaging	fMRI	Jung, et al. (Jung et al., 2018), Chen, et al. (Y. P. Chen et al., 2015), Cascio, et al. (Cascio et al., 2015), Chen and Morris (Chen & Morris, 2016), Venkatraman, et al. (Venkatraman et al., 2015)
	EEG	Chew, et al. (Chew et al., 2016), Goto, et al. (Goto et al., 2019), Yang, et al. (Yang et al., 2018), Harris, et al. (J. M. Harris et al., 2019), Cartocci, et al. (Cartocci et al., 2017), Ramsay, et al. (Ramsay et al., 2018), Yang and Kim (Yang & Kim, 2019), Goto, et al. (Goto et al., 2017), Wei et al. (Wei et al., 2018), Wang, et al. (Wang et al., 2018), Ma, et al. (Ma et al., 2019), Venkatraman, et al. (Venkatraman et al., 2015)
	ERP	Ma, et al. (Ma et al., 2018), Goto, et al. (Goto et al., 2019), Yang, et al. (Yang et al., 2018), Yang and Kim (Yang & Kim, 2019), Goto, et al. (Goto et al., 2017), Wang, et al. (Wang et al., 2018), Ma, et al. (Ma et al., 2019)
Behavioural	IAT	Grigaliūnaitė and Pilelienė (Grigaliūnaitė & Pilelienė, 2017), Pilelienė and Grigaliūnaitė (Pilelienė & Grigaliūnaitė, 2017), Venkatraman, et al. (Venkatraman et al., 2015)
	Self-report	Venkatraman, et al. (Venkatraman et al., 2015)
Physiological	ECG	Cartocci, et al. (Cartocci et al., 2017), Halkin (Halkin, 2018)
	GSR	Andrii, et al. (Andrii et al., 2019), Cartocci, et al. (Cartocci et al., 2017), Halkin (Halkin, 2018), Venkatraman, et al. (Venkatraman et al., 2015)
	Face Reader	Lewinski (Lewinski, 2015)
	ET	Grigaliūnaitė and Pilelienė (Grigaliūnaitė & Pilelienė, 2016), Oliveira and Giraldo (Oliveira & Giraldo, 2019), Pilelienė and Grigaliūnaitė (Pilelienė & Grigaliūnaitė, 2017), Venkatraman, et al. (Venkatraman et al., 2015)

fMRI. Functional magnetic resonance imaging; **EEG.** Electroencephalography; **ERP.** Event-related potential; **Hr.** Heart rate; **GSR.** Galvanic skin response; **ET.** Eye tracking, **IAT.** Implicit Association Test; **EMG.** Electromyography.

Hence, this review includes empirical articles that used physiological and neurophysiological tools to investigate the consumers' reactions toward marketing stimuli (e.g., advertising, branding, product) within a marketing context. We will read, analyse, and summarized these articles in [Table 8](#) to accomplish the purpose of this review paper.

3. Result

3.1. Bibliometric analysis

3.1.1. Leading countries and academic institutions

We have reviewed and analyzed the twenty-four documents from the Scopus database, as tabulated in [Table 2](#). [Table 2](#) demonstrates that almost 50% of the total papers were published by the USA, Spain, Italy, UK, Germany, which lead to infer that these countries are key players in the improvement of NM research. As we can observe from [Table 1](#), the USA is the top producing country in the NM field with almost seventy-seven papers, four of these papers published by Emory University. Spain is considered the second most productive country with forty-eight papers. Followed by Italy, UK, Germany with thirty-eight, thirty-three, thirty papers, respectively. China and Japan were placed in the 6th, 7th, and 8th position in the list of the ten most productive countries with twenty-six, twenty-one, and twenty-one papers, consecutively. Finally, countries that published less than twenty papers such as Malaysia and Turkey with nineteen and seventeen papers.

Although Italy is in the third position among the most ten productive countries around the world, its Università Degli Studi di Roma La Sapienza is considered as the most productive academic institution among other countries institutions with twenty-four papers. Followed by Bucharest University of Economic Studies with twelve papers, then Zhejiang University in China with nine papers. Seven and six papers were published by Universidade da Coruña and the University of Oxford. Emory University, Zeppelin University, Toyama Prefectural University, University Sains Malaysia were contributed with four articles for each one. Finally, Galatasaray Üniversitesi has published three papers.

3.1.2. Leading authors

We have found that the ten most productive authors in the NM topic were affiliated with three countries (e.g., Italy, UK, and China) as shown in [Table 3](#). The total number of publications by these authors was 107 documents. In addition, the four most productive authors in the list are Babiloni,

Table 2. The 10 most productive countries and academic institutions in neuromarketing

Country	TP	The most productive institution	TPi
USA	77	Emory University	4
Spain	48	Universidade da Coruña	7
Italy	38	Università degli Studi di Roma La Sapienza	24
UK	33	University of Oxford	6
Germany	30	Zeppelin University	4
China	26	Zhejiang University	9
Japan	21	Toyama Prefectural University	4
Romania	21	Bucharest University of Economic Studies	12
Malaysia	19	Universiti Sains Malaysia	4
Turkey	17	Galatasaray Üniversitesi	3

TP; total publications; TPi; total publication by institutions

Table 3. The ten most productive authors in neuromarketing topic

Author's name	Year of 1 st publication	TP	TC	H-index	Affiliation	Country
Babiloni, F.	2008	22	508	10	Università degli Studi di Roma La Sapienza	Italy
Vecchiato, G.	2010	17	383	8	Consiglio Nazionale delle Ricerche	Italy
Cherubino, P.	2011	10	147	6	Università degli Studi di Roma La Sapienza	Italy
Astolfi, L.	2008	9	297	6	Università degli Studi di Roma La Sapienza	Italy
Lee, N.	2007	9	473	7	Warwick Business School	UK
Cincotti, F.	2008	8	283	5	Università degli Studi di Roma La Sapienza	Italy
Ma, Q.	2007	8	145	6	Ningbo University	China
Maglione, A. G.	2011	8	152	5	Università degli Studi di Roma La Sapienza	Italy
Mattia, D.	2008	8	283	5	IRCCS Fondazione Santa Lucia,	Italy
Toppi, J.	2010	8	226	5	Università degli Studi di Roma La Sapienza	Italy

TP; total publications; TC; total citations

F., Vecchiato, G., Cherubino, P., and Astolfi, L. from Italy with a total of 22, 17, 10, and 9 documents, 508, 383, 147, and 297 citations, respectively. Lee, N. from the UK, is the most fifth productive author with a total of 9 documents since 2007, 473 citations, and seven h-index. Interestingly, Toppi, J. is the least productive author within the top ten list, with 226 citations and eight h-index.

3.1.3. Journal outcomes

The findings indicate that seven publisher agencies owned the top ten most productive journals, as tabulated in Table 4. Springer Nature has published three documents of them. Followed by Frontiers Media S.A which published two documents. The rest were published by APA, Cogent OA, Elsevier, Emerald, and the Advertising Research Foundation. Moreover, the most productive journal was *Advances In Intelligent System and Computing* with 9 documents. *Frontier in Neuroscience* has published eight documents with 128 citations. *Journal Of Economic Psychology* has published the most cited document among the top ten list with 250 citations, while *Communications In Computer And Information Science* journal was published the least cited document with 6 citations. The answer to the RQ1, the most-cited journal is the *Journal Of*

Table 4. The ten most productive journals in neuromarketing topic

Journal	TP	TC	Cite Score 2019	The most cited articles	Time cited	Publisher
Advances In Intelligent Systems And Computing	9	11	0.9	Analysis of affective and gender factors in image comprehension of visual advertisement	6	Springer Nature
Frontiers In Neuroscience	8	128	5.1	Fusion of electroencephalographic dynamics and musical contents for estimating emotional responses in music listening	54	Frontiers Media S.A.
Lecture Notes In Computer Science	7	28	1.9	Application of frontal EEG asymmetry to user experience research	13	Springer Nature
Journal Of Neuroscience Psychology And Economics	6	150	1.5	Analysis of Neurophysiological Reactions to Advertising Stimuli by Means of EEG and Galvanic Skin Response Measures	109	APA
Cogent Psychology	5	38	1.3	Established liked versus disliked brands: Brain activity, implicit associations and explicit responses	21	Cogent OA
Communications In Computer And Information Science	5	6	0.7	Application of EEG to TV Commercial Evaluation	5	Springer Nature
Frontiers In Human Neuroscience	5	38	5.4	Redefining neuromarketing as an integrated science of influence	22	Frontiers Media S.A.

(Continued)

Table 4. (Continued)

Journal	TP	TC	Cite Score 2019	The most cited articles	Time cited	Publisher
Journal Of Advertising Research	5	60	3.9	How reliable are neuromarketers' measures of advertising effectiveness: Data from ongoing research holds no common truth among vendors	32	The Advertising Research Foundation
Journal Of Economic Psychology	5	250	3.4	Application of frontal EEG asymmetry to advertising research	88	Elsevier
Asia Pacific Journal Of Marketing And Logistics	4	13	3.5	What can neuroscience offer marketing research?	6	Emerald

3.1.4. Keywords analysis

The author keywords co-occurrence analysis carried out in this study involved 1073 keywords from 479 articles in 311 journals. However, a large number of these keywords have been used once. About 1073 keywords were used once, 220 keywords were used twice, and 101 keywords were used triple. The number of total keywords decreased to 1000 by re-labelling them. The keywords were inserted in VOSviewer to map the literature with a minimum of five occurrences, and only 43 keywords met the thesaurus, as depicted in [Figure 3](#). Scholars usually employ co-occurrence analysis as it is an effective method to address the research trends on a particular topic by exploring existing documents (Alsharif, Salleh, & Baharun, 2020; Khudzari et al., 2018), including the marketing field (Wang & Chai, 2018).

Figure 3. The scientometrics map of author keywords co-occurrence (minimum of five occurrences). Using the following URL to open this map in VOSviewer URL: <http://bit.ly/2M8B8rW>.

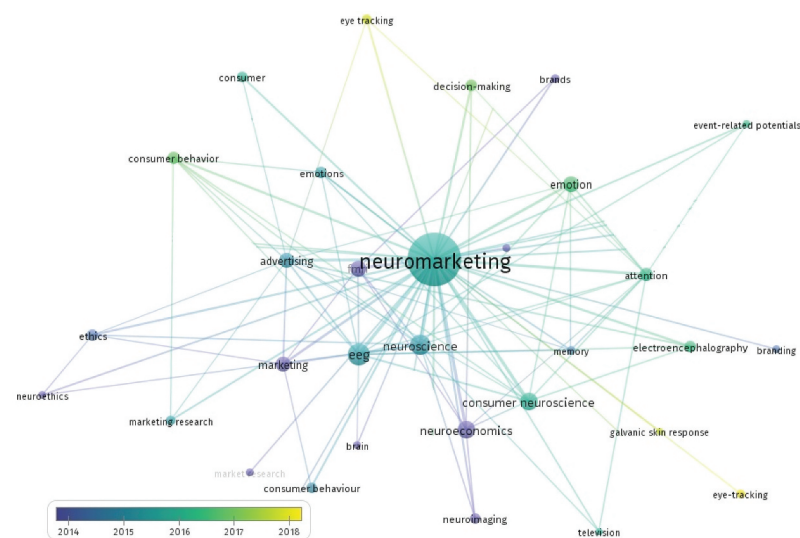


Table 5. Top keywords by the frequency of their occurrence

Keyword	Occurrence/ Frequency	Total link strength
Neuromarketing	274	413
EEG	46	97
Neuroscience	39	97
Consumer neuroscience	31	86
Marketing	21	67
Neuroeconomics	30	64
Advertising	23	63
fMRI	25	60
Emotion	25	59
Attention	18	53
Consumer behaviour	16	45

is second most topics examined concerning NM (46 occurrences, 97 total link strength). Further, neuroscience and consumer neuroscience were observed to be highly associated with NM with 39 occurrences, 97 total link strength, and 31 occurrences, 86 total link strength, respectively. The fMRI device is also had a strong association with NM (25 occurrences, 60 total link strength).

3.1.5. Leading citations

We used citation analysis to identify the most popular articles within the NM environment. It has been suggested that citation analysis counts the number of times other articles cite a particular article to identify the popularity and impact of the article in the scientific field (Baker et al., 2020). Based on the “total times cited count” provided by the Scopus database, we have analyzed the citation of 479 documents. The findings indicate that the documents that have more than 200 citations were published by three different publishers such as Nature Review Neuroscience, Elsevier, and Wiley in five different journals, as tabulated in Table 6. The most cited document was published by Ariely, Dan in 2010, with 388 citations. While the least cited document in the list was published in 2012 by Falk, with 151 citations.

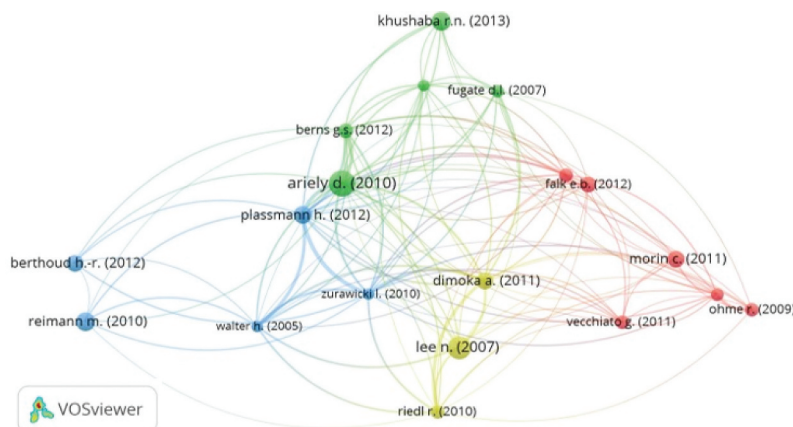
3.1.6. Co-citation network analysis and data clustering

To address the intellectual development of the scope, it has adopted the co-citation network analysis. Consequently, several clusters were identified to conduct the content analysis. To study the structure of the subject “neuromarketing”, we use the VOSviewer program to analyze the co-citation network. The initial findings result is 19 documents with at least 80 citations. To visualize the map of the co-citation, VOSviewer formed a random cluster map that was too complex to understand. Therefore, we identify the ten top documents based on recommended methodology by Kumar and Ranjani (Kumar & Ranjani, 2018), who identified the leading 10 papers from each cluster. In addition, we used the weighted citation count provided by VOSviewer to ensure a high-quality analysis of documents. As shown in Figure 4, the analysis results in four clusters with a high correlation between them. Among the four clusters, the red group is the largest that is led by Morin, C., (2011). Followed by the green cluster with Ariely, D. and Berns, G.S., (2010) as the most dominant study and the most cited author in NM literature. The 3rd blue cluster with Reimann et al., (2010). Finally, the yellow cluster is dominated by Nick, lee et al. (2017). It should be noted that despite that the fact that these clusters address different aspects of NM, they are highly interrelated and complement each other.

Table 6. Top ten articles on Scopus database ordered by citation score (minimum of 150 citations). Using the following URL to open the map in VOSviewer URL: <http://bit.ly/2P3YArH>

Authors/Year	Title	Journal	Publisher	TC 2019
Ariely and Berns (Ariely & Berns, 2010)	Neuromarketing: The hope and hype of neuroimaging in business	Nature Reviews Neuroscience	Nature Reviews Neuroscience	388
Lopes, et al. (Lopes et al., 2015)	Facial expression recognition with Convolutional Neural Networks: Coping with few data and the training sample order	Pattern Recognition	Elsevier	320
Lee, et al. (Lee et al., 2007)	What is neuromarketing? A discussion and agenda for future research	International Journal of Psychophysiology	Elsevier	316
Khushaba, et al. (Khushaba et al., 2013)	Consumer neuroscience: Assessing the brain response to marketing stimuli using electroencephalogram (EEG) and eye tracking	Expert Systems with Applications	Elsevier	211
Reimann, et al. (Reimann et al., 2010)	Aesthetic package design: A behavioral, neural, and psychological investigation	Journal of Consumer Psychology	Wiley Online Library	202
Plassmann, et al. (Plassmann et al., 2012)	Branding the brain: A critical review and outlook	Journal of Consumer Psychology	Wiley Online Library	180
Morin (Morin, 2011)	Neuromarketing: The New Science of Consumer Behavior	Society	Springer	158
Dimoka, et al. (Dimoka et al., 2011)	NeuroIS: The potential of cognitive neuroscience for information systems research	Information Systems Research	Informa Pubs Online	157
Berthoud (Berthoud, 2012)	The neurobiology of food intake in an obesogenic environment	Proceedings of the Nutrition Society	Cambridge University Press	155
Falk, et al. (Falk et al., 2012)	From Neural Responses to Population Behavior: Neural Focus Group Predicts Population-Level Media Effects	Psychological Science	SAGE	151

Figure 4. Map of documents citations 19 articles (minimum of 80 citations). Using the following URL to open this map in VOSviewer URL: <http://bit.ly/2ZAgVOX>.



4. Discussion

This review provides an overview of the studies that employed NM tools in empirical research between 2015 and 2019 to answer research questions (RQ.1, RQ.2, and RQ.3). In addition, it has been used bibliometric analysis to answer RQ.1 and RQ.2 and know the global trends in NM topics based on the outputs of the Scopus database publications from 2004 to 2019. The study revealed that there is a clear interest in NM tools by both academia and industrial environments, which included four main categories: (i) neuroimaging tools, (ii) physiological tools, (iii) self-report tools, and (iv) behavioural measurements tools. According to the literature, there are concerns about the operational restrictions and the implementation cost of neuroscience tools (fMRI), besides, ethical issues such as invasive of consumer's privacy and confidentiality, and autonomy to evaluate consumer's perceptions, preferences and decision-making and the difference between initial estimates and future estimates for neuroscience tools.

We have found that the most generally co-occurring keywords were EEG, fMRI, ERP, and ET, besides, were the closest words from NM as shown in Figure 3. We have reviewed and analyzed the selected articles and we found that the EEG is the most neurophysiological tool that used in articles (approximately thirteen times), followed by the ERP used almost seven times, then the fMRI applied nearly five times. The GSR and ET are the most physiological tools that were used in NM research (almost 4 times for each tool).

The highest number of publications was seven articles in 2018, the total number of citations was 51 times. Additionally, most of the productive countries based on selected articles were China, Malaysia, South Korea, Lithuania, Germany, Brazil, UK, Ukraine, Japan, and Denmark. Based on the authors, among the top 15 authors, South Korea and Malaysia with 3 authors for each country. Lithuania, China, Ukraine with 2 authors per country, and Japan, Germany, and Italy with one author for each country. Chew, et al. (Chew et al., 2016) had the most cited article, with 26 citations. This research has provided an overview of the empirical articles that used NM tools in the last five years.

4.1. Selected article analysis

After identifying and evaluating the papers published on the Scopus database. We found twenty eligible articles for this study. Figure 4 shows the network of collaboration between the twelve productive countries in the NM field.

Table 7 shows that the cluster of countries which were produced empirical articles in the last five years. We can observe that Malaysia and Germany countries have the largest total link strength, followed by Brazil with 302 total link strength. While Ukraine has the lowest total link strength with only two links. For avg. norm. citations, Italy has the highest avg. norma. citations with 3.43, followed by USA and Denmark with 2.33 avg. norm. citations for each country. At lowest avg. norm. Citations were given to Brazil. Table 8 shows the analysis and summary of the selected articles for this review study.

Table 7. Clusters of countries that produced the empirical article in the last five years

Category	Country	Links	Total Link Strength	Avg. norm. citations
Cluster 1	UK	9	296	1.79
	Italy	10	31	1.93
	Australia	10	23	3.43
	Ukraine	2	2	1.20
	South Korea	3	13	0.46
	China	11	128	0.65
Cluster 2	Brazil	10	302	0.43
	Japan	9	293	0.86
	Malaysia	9	478	1.47
	Germany	9	478	1.39
Cluster 3	USA	9	126	2.33
	Denmark	9	126	2.33

5. Implication of the research findings for theory and practice

Theoretically, the current findings can be divided into three folds, as follow: Firstly, physiological tools such as ET, GSR, EMG, and ECG can provide beneficial insights about the physiological correlate of consumer behaviour, while neuroimaging tools such as fMRI and EEG enables to capture the neural correlates of emotion processes(e.g., pleasure, motivations, and arousal), cognitive processes (e.g., attention, recall, recognition, and memory) toward marketing stimuli such as advertisements and brands. Secondly, marketers and advertisers will be able to identify the attractiveness and aversion aspects in advertising campaigns before using them in the real world; therefore, recognize the aspects that cause aversion attitude toward advertising and fix them, additionally, reinforce the strengths aspects that drive the consumer to pleasure and making decisions. Third, the majority of the studies focused on detecting the impact of advertising campaigns on consumers' behaviour; therefore, the ability to predict consumer behaviour. In addition, there are some studies focused on spokesperson's gender, ads appeal, warm colour temperature and cool colour temperature, celebrity face, social initiatives (i.e., anti-smoking), and public health in advertising campaigns. Therefore, these three folds together can explain the neural and physiological correlates of motivation, reward, and perception processes of interest for advertising. An application of this research might offer measurable explanations of how advertising works in consumers' minds which is reflected in the bodily responses of consumers, thereby, creating attractive advertising in several domains such as political, social and business.

6. Conclusion and future work

NM plays a vital role whether in social advertisements or commercial advertisements. This study was conducted to concentrate on studies that employed the NM tools in practical research from 2015 to 2019, wherein authors found that the EEG is more common in experiments in the NM field because it has excellent temporal accuracy and less cost. It also used a bibliometric analysis to understand the global research trends in the NM field based on the outputs of academic publications such as the most-cited article and journal. Along with a literature review to evaluate and analyze the previous studies that employed NM tools in empirical research such as neuroimaging, physiological, and behavioural tools. It was analyzed 24 empirical articles from the Scopus database and it was noticed that NM research has increased globally since 2004. The authors identified, reviewed, and analyzed the relevant articles to know how these studies used the most common words. Then these studies were summarized and their major contribution and findings were detailed in [Table 8](#).

Table 8. A summary of the selected articles that were discussed in this research to identify the titles, objectives, methods, findings, and limits of the studies

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Andrii, et al. (Andrii et al., 2019)	Attractiveness modeling of retail on emotional fatigue of consumers	Trying to study emotional fatigue and its impact on choosing the retailer and the purchase decision process.	GSR	The atmosphere in the store and the consumer's state impact the emotional fatigue differently; thereby, the footfall.	15 different retailers shops
Goto, et al. (Goto et al., 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	The accuracy of prediction toward consumer's preference to specific products is almost 70.8% by using SI-ERPs, and also the accuracy vary 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.	Twelve specific product pictures
Harris, et al. (J. M. Harris et al., 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	Emotion-based advertisements are more effective than rational-based advertisements; thereby, led to positive change in decision-making, increasing donation, and more liking.	Public health advertisements in Australia.

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Yang and Kim (Yang & Kim, 2019)	Group-level neural responses to the service-to-service brand extension	Investigating the consumers' neural processes related to the judgment of brand extension and propose the new stimulus to find appropriate S2S brand extension.	EEG/ERP	Showing that the neural processes engaged in assessing the S2S brand extension may be involved in assessing the G2G brand extension. In addition, the left frontoparietal P300 may provide neural evidence for the acceptability of a new S2S brand extension.	brand extension
Oliveira and Giralddi (Oliveira & Giralddi, 2019)	Neuromarketing and its implications for operations management: an experiment with two brands of beer	Discussing the influence of well-known brands advertising on adults visual selective attention during consumption of alcoholic beverages. Besides, Helping to create more effective products and advertising campaigns.	Eye-tracking (Tobii Eye-Tracking hardware model X1L)	There are remarkable differences in visual selective attention among young adults, wherein the strong brand had greater visual attention compared with others.	Alcoholic beverages
Ma, et al. (Ma et al., 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 people and Chinese people) toward brand preference.	EEG/ERP	The logo of the brand has highly influenced the Chinese participants' preference toward brands.	Brand logo preference
Wang, et al. (Wang et al., 2018)	The effects of money on fake rating behavior in e-commerce: Electrophysiological time course evidence from consumers	Exploring whether RN or RI strategy is more strongly impact the online fake rating behavior of the consumers.	EEG/ERP	RI strategy has more impact on the online fake comments behavior of the consumer.	Online fake comments behavior
Wei, et al. (Wei, Wu, Wang, Supratak, Wang, Guo 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	The percentage of purchasing power was relatively high after watching the advertising.	Purchasing intention

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Ma, et al. (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	The participants' price perception was highly influenced by participants' emotions (win/lose experience), emotions produced from continuous/ single wins were more positive than continuous/ single losses. While continuous wins/loses evoked more intense emotions compared to single win/lose.	sixty hard-disc pictures
Yang, et al. (Yang et al., 2018)	Characteristics of human brain activity during the evaluation of service-to-service brand extension	Investigating neural activities of cognitive processes underlying the assessment of service-to-service brand extension. In addition, developing a method of grouping stimuli to find the fit levels of behavior responses toward a service-to-service brand extension.	EEG/ERP	It can elicit higher positive amplitude in P3 by low-fit stimuli. While mid and high-fit stimuli elicited higher negative amplitude at N400. Whereas low, mid, and high-fit did not show any significant difference at N2. The cognitive neural activity might differ between S2S brand extension and G2G brand extension.	56 text stimuli.

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Halkin (Halkin, 2018)	Emotional state of consumer in the urban purchase: processing data	Estimating the consumer's emotional state (emotional fatigue) during the visit to any shop.	GSR (NeuLog GSR) and heartbeats per minute (BPM) (NeuLog Pulse)	Entering the consumer to the supermarket, then take demanded products, and waiting in the cashier line generates a consumer's emotional reaction, which refers to an increase of consumer's fatigue index inside the shops and decreases on the road back to home, overall it is still higher than at home situation.	Emotional fatigue
Ramsoy, et al. (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	Illustrating that asymmetry in the prefrontal cortex in the gamma and beta band was highly related to subsequent WTP responses, and the gamma band was most strongly related to WTP decision.	WTP
Jung, et al. (Jung et al., 2018)	The neural correlates of celebrity power on product favorableness: An fMRI study	Investigating the neural correlates of celebrity power in influencing the car favorableness in advertising.	fMRI	The rewards, memory, semantics, and attention regions in the brain were lighted up with viewing a combination of celebrity face and a car compared with viewing a combination of non-celebrity face and a car. In addition, a car favorableness correlated positively with activation in the left anterior insula, left OFC, and left higher-order visual cortex in the OL.	Celebrity face and favorableness car

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Pilelienė and Grigaliūnaitė (Pilelienė & Grigaliūnaitė, 2017)	Relationship between spokesperson's gender and advertising color temperature in a framework of advertising effectiveness	Studying and analyzing the influence of color temperature of pictures and the gender of spokesperson on the advertising effectiveness.	Eye Tracking (Tobii Eye-Tracking Glasses)	The warm color temperature attracts more visual attention to the advertisement; thereby, generates a positive implicit attitude to the advertisement and induces the buying intentions of the advertised products compared with cool color temperature advertisements whether the spokesperson's female or male celebrity. Therefore, The color temperature impacts the effectiveness of the advertising spokesperson and advertising effectiveness.	10 pictures (5 warm color temperature (3000 K) and 5 cool color temperature (6000 K)) once with female celebrity, and once with male celebrity.
Goto, et al. (Goto et al., 2017)	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	The variations in subjective preferences toward goods have strongly modulated PSW and LPP by subsequent purchasing decisions. Therefore, LPP and PSW could reflect conscious cognitive processes (e.g., selective attention).	The selective attention markers

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Grigaliunaite and Pileliene (Grigaliunaite & Pileliene, 2017)	Attitude toward smoking: the effect of negative smoking-related pictures	Identifying the explicit and implicit attitudes of individuals toward smoking by determining the impact of a negative picture of smoking.	IAT and Questionnaire	The consumers' attitude was highly impacted the purchase decisions. In addition, conventional methods lack to measure explicit attitude accurately; thereby, both NM and conventional marketing methods complement each other to reveal the consumers' attitude.	Pictures
Cartocci, et al. (Cartocci et al., 2017)	Electroencephalographic, heart rate, and galvanic skin response assessment for an advertising perception study: Application to antismoking public service announcements	Presenting a series of methods that could lead to the accurate measurement of the cerebral and emotional perception of antismoking PSAs.	EEG, HR, and GSR	A campaign of PSAs characterized by a symbolic communication style obtained the highest approach values, as evaluated by the AW index. While an image and a spot based on the "fear arousing appeal" and with a narrative style reported the highest and lowest effort values index, respectively. Also, the same "effective" campaign showed the highest EI values.	Social Campaign (antismoking)
Chew, et al. (Chew et al., 2016)	Aesthetic preference recognition of 3D shapes using EEG	Identifying the process and approach to recognizing individuals' aesthetic preference for 3D shapes.	EEG	The rhythms from frontal channels Fz, F3, and F4 are suitable for the identification of human preference (e.g., like and dislike) toward moving 3D shapes.	Aesthetic preference

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Chen and Morris (Chen & Morris, 2016)	Decoding neural responses To emotion in Television Commercials	To measure emotional response to TV ads	fMRI	The dimensions of emotion (e.g., appeal, engagement, and empowerment) are playing a vital role in measuring feelings toward TV ads.	TV ads
Grigaliunaite and Pileliene (Grigaliunaite & Pileliene, 2016)	Emotional or rational? The determination of the influence of advertising appeal on advertising effectiveness	Determining the impact of outdoor advertising effectiveness; thereby, developing the model of the influence of advertising appeal on advertising effectiveness.	Eye-tracking (Tobii Eye Tracking Glasses), IAT, and Questionnaire	Firstly, in the cognitive stage to consumer's response toward print/ outdoor advertising can achieve effectiveness by applying either the emotional or rational appeal. Secondly, in the affective stage, the application of emotional advertising appeal is more effective. Lastly, in the conative stage, the application of rational advertising appeal is more effective.	Ads appeal
Lewinski (Lewinski, 2015)	Don't look blank, happy, or sad: Patterns of facial expressions of speakers in banks' YouTube videos predict video's popularity over time	Proposing that the popularity of YouTube videos on social media platforms could be predicted by nonverbal expressions (facial expressions).	Face Reader version 6.0	Decreasing incidence of affiliative facial emotions (happiness and sadness) and increasing incidence of non-emotional expressions (surprise) explained up to 86% in the video's popularity. In short, A simple and non-emotional non-verbal message is what viewers and potential customers (e.g., social media users) find most compelling.	YouTube videos

(Continued)

Table 8. (Continued)

Author & Year	Title	Major contribution	Method (Device)	Finding summary	Limit of the Study
Venkatraman, et al. (Venkatraman et al., 2015)	Predicting Advertising Success Beyond Traditional Measures: New Insights from Neurophysiological Methods and Market Response Modeling	To assess subjects' responses to 30-second TV ads, and to relate individual-level response neurophysiological measures when participants viewed the ads.	fMRI, EEG, ET, IAT, Self-report, Biometrics (heart rate, breathing, SCR/EDR)	The fMRI measures allows to explain the variance in TV advertising much better than traditional measures.	TV Advertising
Cascio, et al. (Cascio et al., 2015)	Neural correlates of susceptibility to group opinions in online word-of-mouth recommendations	To examine the relationship between social influence and recommendation decisions among teenagers in the new media environment	fMRI	Changes in recommendations as a result of peer recommendations have been increased activity in the striatum and the OFC.	Recommendation decisions and social influence on adolescent decisions
Chen, et al. (Y.-P. Chen et al., 2015)	From "Where" to "What": Distributed Representations of Brand Associations in the Human Brain	Combining between machine learning tools with fMRI data to describe the relationship between brand personality and brain activity.	fMRI	It is possible to predict the brand that person is thinking of it based on the correlation between brand personality and brain activity.	Brand personality

SI-ERPs. Single-item ERPs; **LPP.** Late positive potential; **PSW.** Positive slow waves; **S2S.** Service to service; **G2G.** Goods to goods; **N.** Negative polarity; **P.** Positive polarity; **EI.** Emotional index; **AW.** Approach withdrawal; **PSAs.** Public service announcements; **BPM.** Beat per minute; **PFC.** Prefrontal cortex; **WTP.** Willingness to pay; **OFC.** Orbitofrontal cortex; **RN.** Returning and no; **RI.** Returning and if; **OL.** Occipital lobe.

Nevertheless, this study can be useful for future research trends as it gives previous studies of the research subject/problem. The authors would recommend that future research on NM has to use the fMRI tool to evaluate and predict the purchase processes and decision-making by determining the activity regions in the consumer's brain; thereby, predicting the success or failure of the product or advertisements before put it in the real environment due to that it has an excellent spatial resolution, besides, can record the distal regions in the brain accurately unlike EEG. In addition, we suggest that scholars should focus on the contributions of NM research in other domains such as social sciences, politics.

7. Limitations of the study

We tried to minimize the shortcoming in methodology, this study comes with a limitation that offers opportunities for future research. We focus on extracting the publications from the Scopus database that were published in the last five years. In addition, we extracted empirical papers that were published in the English language and employed NM tools and overlooked the books, chapter books, proceeding books, notes, reviews, conferences and the non-English language publications, thereby the current study is not fully bias-free.

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