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Literature review article

Neuromarketing: Its current status and research perspectives

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Abstract
This document aims to conduct a literature review in order to identify evolution and research trends in the area of neuromarketing. To achieve this objective, a science mapping approach was adopted. Science mapping is an innovative and appropriate tool used in systematic literature reviews by integrating bibliometrics and network analyses. In the case of this paper, an exploration of the Web of Science (WoS) and Scopus databases was carried out. The records obtained enabled the construction of the network of the most relevant documents in the field, which were categorized into "classical", "structural", and "recent". This process allowed for the identification of three perspectives or research correlates. Additionally, it became evident that neuromarketing is still an immature and incipient area with a low degree of theoretical consensus.

Keywords: neuromarketing; consumer neuroscience; consumer behavior; scientific mapping; bibliometrics; systematic review.

Neuromarketing: su estado actual y perspectivas de investigación

Resumen
Este documento tuvo como objetivo llevar a cabo una revisión de la literatura para identificar la evolución y las tendencias de investigación en el área de neuromarketing. Para ello, se empleó un enfoque de mapeo científico como herramienta innovadora y apropiada para desarrollar revisiones sistemáticas de literatura, que integra la bibliometría y el análisis de redes. Se realizó una exploración de las bases de datos Web of Science y Scopus. Los registros obtenidos permitieron la construcción de la red de los documentos más relevantes en la materia, los cuales fueron categorizados en clásicos, estructurales y recientes. Este proceso permitió identificar tres perspectivas o corrientes de investigación. Además, se evidenció que el neuromarketing todavía es un área inmadura e incipiente con un bajo grado de consenso teórico.

Palabras clave: neuromarketing; neurociencia del consumidor; comportamiento del consumidor; mapeo científico; bibliometría; revisión sistemática.

Neuromarketing: seu estado atual e perspectivas de pesquisa

Resumo
Este documento teve como objetivo realizar uma revisão da literatura para identificar a evolução e tendências de pesquisas na área de neuromarketing. Para isso, foi utilizada uma abordagem de mapeamento científico como ferramenta inovadora e adequada para desenvolver revisões sistemáticas de literatura, que integra bibliometria e análise de redes. Foi realizada uma exploração nos bancos de dados Web of Science e Scopus. Os registros obtidos permitiram a construção da rede dos documentos mais relevantes sobre o assunto, os quais foram categorizados em clássicos, estruturais e recentes. Esse processo permitiu a identificação de três perspectivas ou correntes de pesquisa. Além disso, evidenciou-se que o neuromarketing ainda é uma área imatura e incipiente com baixo grau de consenso teórico.

Palavras-chave: neuromarketing; neurociência do consumidor; comportamento do consumidor; mapeamento científico; bibliometria; revisão sistemática.

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1. Introduction

Since its inception, marketing has been nourished by multiple disciplines and applications including basic sciences, social sciences, economics, and engineering (Weitz & Wensley, 2006). Despite using concepts and ideas from various sciences, it is a robust and continually evolving field. Markets are changing radically, along with how products and services are created, delivered and consumed (Achrol & Kotler, 2012). Consumers are also playing an increasingly prominent role due to their participation in the processes of product and service innovation (Martínez-Cañas, Ruiz-Palomino, Linuesa-Langreo, & Blázquez-Resino, 2016). It is therefore important to better understand their behavior.

Recent neuroscientific developments regarding the structure of the brain and its functioning have led to new ways of understanding the consumer and neuromarketing (Lim, 2018). This new field of knowledge is gradually becoming an essential complement to marketing research (Duque, 2014; Plassmann, Venkatraman, Huettel, & Yoon, 2015).

This field of study has attracted increasing interest from the scientific community in recent years. Despite the fact that several reviews have previously been done on the subject (Lee, Broderick, & Chamberlain, 2007; Lim, 2018; Plassmann, Ramsøy, & Milosavljevic, 2012; Victoria, Arjona, & Repiso, 2015; Yağci, Kuhzady, Balik, & Öztürk, 2018), this article aims to address methodological approaches and limitations; for example the use of a single database, restricted search topics, exclusion of journals by type, and document types. In addition, none of the reviewed studies uses network analysis to explore the subject. Accordingly, the objective of this paper is to carry out a literature review based on scientific mapping techniques to determine the evolution of neuromarketing and its research trends.

To meet this objective, an initial search was carried out on Web of Science (WoS) and Scopus; the results were processed using the R, Sci2 Tool, and Gephi software. The tree analogy (root, trunk, and leaves) was used to classify the documents under analysis. Finally, the differing currents or perspectives of neuromarketing research were determined.

This remainder of this paper is divided into four additional sections. In section 1, other literature reviews on neuromarketing are analyzed. Section 2 describes the methodology used for monitoring, selecting, and processing the main research articles. In section 3, the development of the research is presented. Finally, in section 4, the conclusions, limitations of the study and recommendations for further research of this type are explained.

2. Preliminary literature reviews

Neuromarketing is a new marketing application of behavioral neurosciences. The tools of neuromarketing identify decision-making processes that are invisible to the naked eye. The application of science allows us to understand not only the decision-making process, but also the shopping experience. Advances in neurosciences also allow the use of 2D and 3D models to effectively analyze these processes (Solomon, 2018).

Through database searches, some bibliometric studies and reviews on neuromarketing were identified, listed, and described. One of the most referenced reviews is that of Lee et al. (2007), whose results lead the authors to affirm that there is a highly fragmented literature and a lack of signposting, which makes it very difficult for novices to find the relevant work and journal outlets. That review also highlights a lack of high-quality and user-oriented methodologies, the first aspects that a novice would need. They state that neuromarketing, as it appears to a novice, lacks clear guidance on what defines good vs. bad neuromarketing research. As a vast majority of the reviewed papers have appeared in lower-ranked journals, amateurs may be subject to a biased view of what constitutes acceptable research standards in the field.

Plassmann et al. (2012) identify the possibility of analyzing the consumer psychology of brands, thanks to the application of neuroscience in marketing, where the academic and the corporate world have found their own space. They describe critical issues of past research and discuss how to address these issues in future studies; they also find considerable research potential at the intersection of neuroscience and consumer psychology.

Likewise, Victoria et al. (2015) conducted their bibliometric study and found that the main applied areas were economics and business (as well as social sciences), while the primary production of this type of article, coming from neuroscience areas, did not have the first place in academic production.

Later, Lee, Chamberlain and Brandes (2018), upon resuming their research, recognized that neuroscientists can directly study the frequency, location, and timing of neuronal activity to an unprecedented degree. However, they acknowledge the controversy of handing the responsibility of building real marketing science to commercial applications, as that process requires the intervention of trust, pricing, negotiation, and ethics variables. This provides a new perspective that validates neuromarketing as a scientific field of study and proposes to find a bridge between neuroimaging and marketing research groups. Both fields have much to learn from mutual perspectives, and scholarly neuromarketing research "conducted in a collaborative and non-judgmental spirit, is likely to offer us much insight into how humans behave during a large part of our modern lives." (Lee et al., 2007, p. 203).

Concurrently, Lim (2018) proposed that the goal of neuromarketing is to adapt theories and methods from neuroscience and combine them with theories and methods from marketing and related disciplines (such as economics and psychology) to develop neuroscientifically sound explanations of the impact of marketing on target customer behavior.

Finally, Yağci et al. (2018) noted that while marketing is trying to understand the psychology of human behavior, neuromarketing is trying to understand the *biology* of human behavior. He asserts that the success of neuromarketing is based on the inefficiency of traditional data collection methods. Therefore, understanding and analyzing consumer behavior, proper product development, packaging, and logo design in a distinct way would satisfy current consumer needs and wants, and lead to more effective promotional tools. This piece of research facilitated the identification of research topics, trends, and interests that may serve as a guide for future research. A total of 1,527 keywords were retrieved from the 351 chosen articles. Eye-tracking was the most-used keyword, followed by neuromarketing, attention, neuroscience, EEG, and fMRI.

3. Methodology

In order to fulfill the aforementioned objective, a search in WoS and Scopus databases on the subject of neuromarketing was first carried out. The results (754 records) were then exported and processed through the Bibliometrix tool, which facilitates bibliometric analysis (co-citation networks, co-authorships, production by country and author, journals and their impact rankings). Afterwards, the references (bibliography) of the 754 records were extracted through the Sci2 Tool application and a total of 9,182 items were obtained. Finally, a social network integrating all the references was generated with the Gephi tool. The data resulting from the processes mentioned was presented through a tree diagram: classical documents (hegemonic) were placed in the roots, structural ones were placed in the trunk, and recent ones (perspectives) were placed in the leaves.

The study was carried out between January 2001 and December 2019. In the WoS databases a total of 18,000 registered journals were found, whereas Scopus currently holds 39,647 registered journals. These two sources were chosen because they are considered the most important databases (Bar-Ilan, 2008), thanks to their broad content of scientific production (Bar-Ilan, 2008, 2010; Gavel & Iselid, 2008; Vieira & Gomes, 2009). WoS and Scopus were also chosen to retrieve the documents based on the limitations and recommendations of previous reviews (Lee et al., 2007; Plassmann et al., 2012; Victoria et al., 2015; Lim, 2018). Table 1 shows the search criteria.

The references extracted from the databases were obtained through a classification of content by author, title, year, DOI, source and references that later made up a network. This procedure involved articles from different journals and sources (indexed and non-indexed), regardless of their database or language, which allowed an in-depth visualization of the field of study in terms of more inclusive academic production.

Table 1. Search criteria

Filters	Database	
	Web of Science	Scopus
Searches	Title, abstract, author keywords, and Keywords Plus.	Title, abstract, keyword
Time restriction	2001-2019	
Document type	Article, books, book chapters and conference papers	
Journal type	Any	
Keyword combination	"Neuromarketing"	
Total per database	278	476
Total documents	754	

Source: own elaboration.

The methodology proposed by Robledo, Osorio and Lopez (2014) in which the articles are organized into three tree-shaped perspectives has been used in multiple papers (Buitrago, Duque, & Robledo, 2020; Duque-Hurtado et al., 2020; Salazar, Álvarez, Garcés, & Duque, 2020; Duque & Duque, 2020; Duque & Cervantes-Cervantes, 2019; Hernández-Leal, Duque-Méndez, & Moreno-Cadavid, 2017; Toro & Rodriguez, 2017; Zuluaga et al., 2016). Such a proposal places the research that gives support to the theory in the roots, the research that is beginning to shape theory (i.e. specific articles on a topic that become references over time) in the trunk, and diverse articles related to the most current perspectives in the leaves.

Graph theory was used to create the map that allows the visualization of articles and their relationships to one another. This theory is used by a large number of studies in the field of social sciences (Wasserman & Faust, 1994). It is a technique that works effectively in extracting outstanding information from the characteristics and topology of the network; to this end, two tools were used: the Sci2 Tool in which the list of references and citations extracted from the databases are entered and transformed into a network, and Gephi, which makes it possible to observe and study the network (Bastian, Heymann, & Jacomy, 2009).

The Bibliometrix R-package was used to perform a bibliometric analysis, since it is an open source tool that facilitates scientific mapping (Aria & Cuccurullo, 2017). Several pieces of research in different disciplines that require scientific mapping have chosen to use it (Addor & Melsen, 2019; Almeida & de Paula, 2019; Bond & Buntins, 2018; Medina et al., 2018).

After the creation of the network, the related indicators could be visualized and calculated using the Gephi tool. The "Indegree" indicator refers to the number of times the articles in the network have cited another one, while the "Outdegree" refers to the number of times a specific article quotes others in the network or to the number of links directed away from it (Wallis, 2000). In the Gephi software each article is represented by a node and each connection by an edge.

In addition, the giant component filter that searches and locates directly or indirectly linked nodes was used, excluding those that are not linked to the main community (Bollobas, 1984). "Betweenness" was the last filter used; it estimates the number of optimal paths in the network that cross a node (Freeman, 1977). The resulting node will have high levels of intermediation and centrality because it interacts with a large number of nodes in the network (Ni, Sugimoto, & Jiang, 2011), precisely, connecting the classical articles with the most current ones. Finally, the network resulting from the application of the mentioned components was made up of 1,290 nodes (references), from which the documents with the highest indicators were chosen for analysis.

4. Results

4.1 Neuromarketing Academic Production

Figure 1 shows scientific production associated with neuromarketing in the Scopus and WoS databases from 2004 to 2019 (736 documents). Until 2009, 38 documents had been published, making it the period with the lowest productivity; however, from this year onwards the interest of the scientific community in this area grew significantly. During 2019 (the period of highest production) 128 articles were published, which constitutes 17% of total publications. The trend lines show an increase of interest in the field, which is reflected in an annual growth rate of 31%.

Regarding the analysis of scientific production by country, the United States leads the way in both databases, with 43 publications in WoS and 72 in Scopus. Figure 2 provides a list of the 10 countries that lead academic publications in neuromarketing; 8 of them (United States, Spain, Italy, Germany, United Kingdom, China, Japan, and Turkey) are in the top 10 in both databases.

The countries that populate these lists carry out 70% of global research on the subject of neuromarketing. The United States produces 24% of these publications and European countries produce 52% (Figure 2).

Table 2 provides a list of the most relevant authors and classifies them by the number of publications in each database, their h-index (an indicator proposed by Hirsch (2005) used to characterize the level of researchers' scientific production) is also associated. Fabio Babiloni is the researcher with the highest number of publications in both databases, followed by Giovanni Vecchiato and Laura Astolfi; all three are co-authors of multiple articles (Astolfi et al., 2007b; Babiloni et al., 2005; Borghini, Astolfi, Vecchiato, Mattia, & Babiloni, 2014). Furthermore, Babiloni has an h-index of 66, the best within the list of the most relevant authors.

Figure 3 shows the authors' co-citation network. This analysis is a bibliometric technique based on the co-occurrence of article references, which allows the characterization of the structure of a field of study from the co-cited authors (Culnan, 1986; White, 2003; White & Griffith, 1981). Authors with conceptual affinities in their research tend to cite each other. Of course, some are more relevant than others, allowing them to stand out (McCain, 1990; Sircar, Nerur, & Mahapatra, 2001). Within the network, authors such as Plassmann, Knutson, Ariely, Lee, Kenning, Mcclure and Vecchiato are the most cited, and even the four most relevant documents (with respect to the number of citations) in this field of study are those in which Knutson, Ariely, Lee and Mcclure participate as authors (Figure 3). Two clusters can also be identified (only the most relevant researchers are mentioned): the largest consisting of Lee, Knutson, Plassmann, Kenning, Mcclure; and the second one including Ariely, Vecchiato, Zaltman and Ohm.

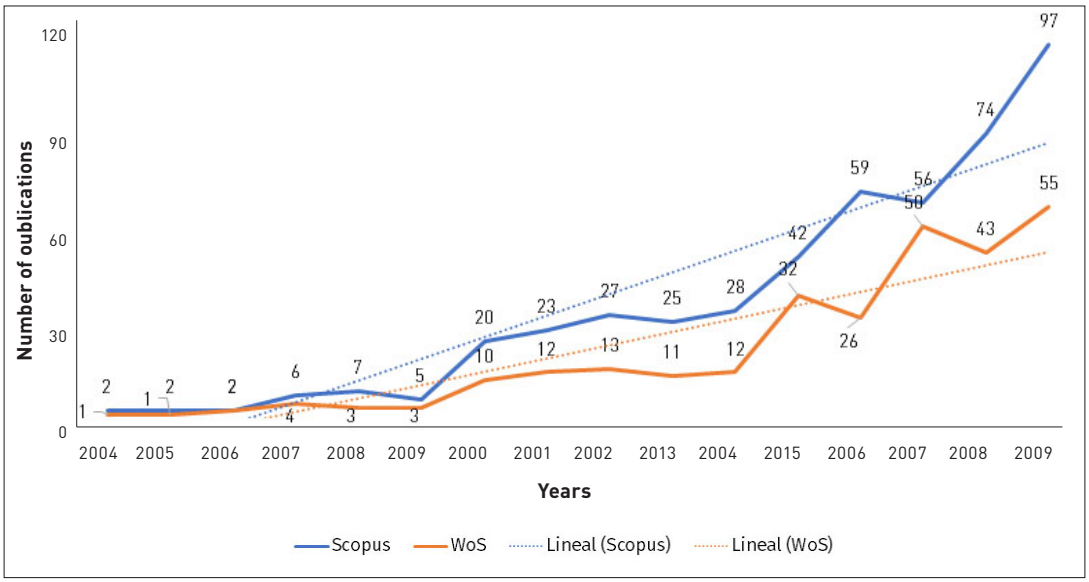

Figure 1. Neuromarketing scientific production
Source: own elaboration.

Table 2. Most relevant authors

Scopus			WoS		
Author	Number of publications	h-index	Author	Number of publications	h-index
Babiloni F.	22	66	Babiloni F.	11	66
Vecchiato G.	17	23	Ma Q.	11	18
Astolfi L.	9	42	Vecchiato G.	8	23
Cherubino P.	9	11	Lee N.	7	32
Cincotti F.	8	62	Astolfi L.	6	42
Lee N.	8	32	Cincotti F.	6	62
Ma Q.	8	18	Grigaliunaite V.	6	7
Maglione AG.	8	11	Mattia D.	6	46
Mattia D.	8	46	Pileliene L.	6	10
Toppi J.	8	17	Wang XY.	6	27

Source: own elaboration.

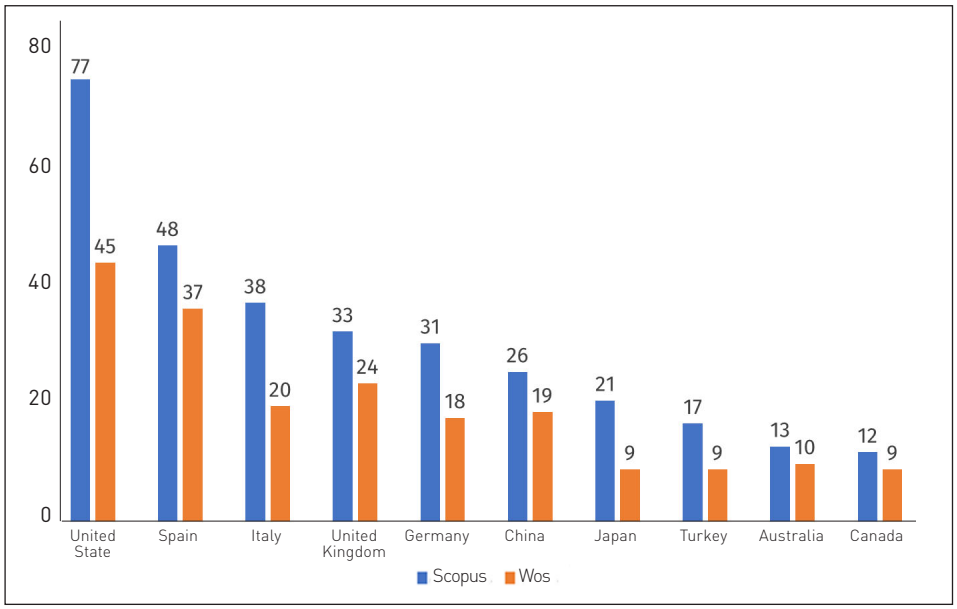

Figure 2. 10 Countries with the highest production
Source: own elaboration.

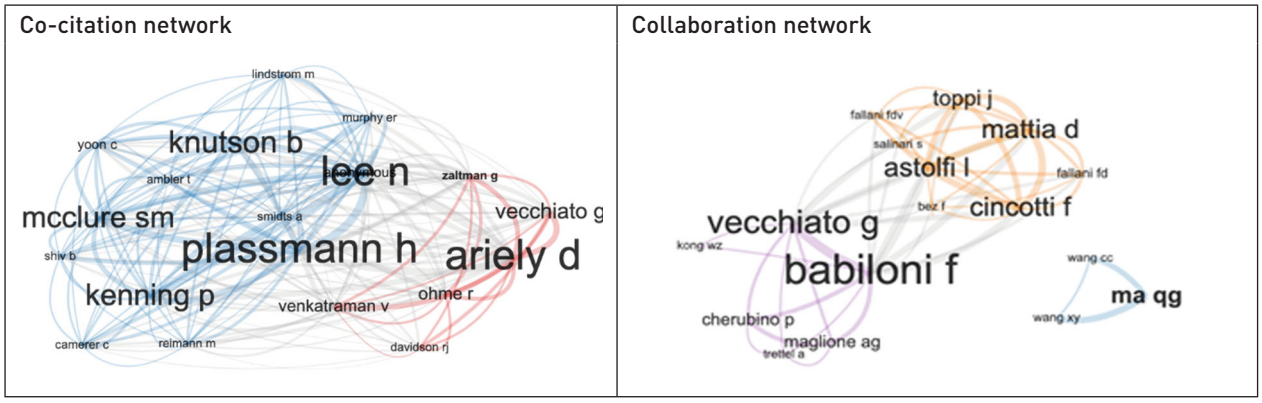

Figure 3. Network
Source: own elaboration.

Table 3. Most important journals

Journal	Articles	Impact factor	Quartile	Data base
Frontiers In Neuroscience	11	3.64	Q2	WoS
	9	1.67	Q1	Scopus
Advances in Intelligent Systems and Computing	9	0.17	Q3	Scopus
Lecture Notes in Computer Science	7	0.28	Q2	Scopus
Journal of Neuroscience Psychology and Economics	6	0.47	Q1	Scopus
International Journal of Market Research	6	3.64	Q4	WoS
	6	0.29	Q2	Scopus
Frontiers in Human Neuroscience	5	1.28	Q1	Scopus
	4	2.87	Q1	WoS
Cogent Psychology	5	0.32	Q3	Scopus
European Journal of Marketing	5	1.71	Q1	WoS
Journal of Economic Psychology	5	1.04	Q1	Scopus
Comunicar	4	3.33	Q1	WoS

Source: own elaboration.

Figure 3 shows the network with a strong collaboration among authors such as Babiloni, Vecchiato, Astolfi, Cincotti, Mattia, Fallani and Toppi, which creates a community among these researchers. Another group of co-authors represented by Ma Q., Wang XY. and Wang CC. show another community, but not as important in relation to the number of publications and impact of their authors as the first one.

Table 3 lists the 10 journals (indexed in WoS and Scopus) with the largest number of published articles on neuromarketing. It also shows their impact factor and their quartile according to the database. The most important journal in this field is Frontiers in Neuroscience, a Swedish publication with an h-index of 71 and classified in Q1 by Scopus and Q2 by WoS.

4.2 Network analysis

The search equation produced an initial network composed of 9,162 nodes and 12,556 links; after processing them a final network of 260 nodes and 4031 links was established. The main inclusion criteria for choosing which documents to analyze were: In-degree (degree of entry, number of times a document is cited by others that are part of the network), Betweenness (degree of intermediation, citation of and by other documents in the network), and Out-degree (degree of exit, citations made to other documents in the network). A total of 40 documents were selected for this review: 10 articles with the highest level of In-degree, 15 with the highest level of Betweenness, and 15 with the highest level of Out-degree that involve relevant information over an extended period of time. The classical (hegemonic) documents have high Out-degree and zero In-degree, the current (recent) documents have high In-degree and zero Out-degree, and the structural documents have high Intermediation, which implies that they connect classical studies to current ones. The documents are presented through a tree structure, in which the classical documents are the roots, structural ones form the trunk and current ones are the leaves.

The Neuromarketing network (Figure 4), composed of 260 documents, was obtained through the use of the Modularity Class algorithm that allows the selection of different communities (clusters) within the network by separating the nodes that are more densely connected (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008); in this case 3 perspectives were identified. The size of the nodes (documents) represents the degree to which they are cited; the largest ones are those which have been cited most frequently within the network, which implies that they are the most relevant in this field of study. The four most important nodes are highlighted.

4.3 Classical documents

The documents considered to be hegemonic (Table 4) can be classified into two groups: the first includes theoretical research (Murphy, Illes, & Reiner, 2008; Fugate 2007; Plassmann et al., 2012) and the second includes experimental research (Deppe, Schwindt, Kugel, Plasmann, & Kenning, 2005; Erk, Spitzer, Wunderlich, Galley, & Walter, 2002; Knutson, Rick, Wimmer, Prelec, & Loewenstein, 2007; McClure et al, 2004; Plassmann, O'Doherty, Shiv, & Rangel, 2008; Astolfi et al., 2009; Yoon, Gutchess, Feinberg, & Polk, 2006).

4.4 Theoretical research

The following authors, who analyze conceptual components of applications, are located in this group. Fugate (2007) describes the origins of neuromarketing and explains it in simple terms, lists some of the findings of various studies to date, and suggests future directions for research on consumer behavior. This author concludes that the use of neuroscience techniques such as neural activity imaging can support conventional marketing techniques and improve their effectiveness. Hubert and Kenning (2008) agree with the views discussed by Fugate, however, they state a difference between consumer neuroscience and neuromarketing; for these authors the former is a scientific procedure, but the latter is the application of the findings of neuroscience to management practices. They conclude that consumer neuroscience is an emerging field of study that can meaningfully complement consumer studies. Finally, Murphy et al. (2008) propose a preliminary code of ethics that promotes research and development of this field of study, considering business profitability without putting consumers at risk.

Table 4. Hegemonic documents

Document	Reference	Citations
Cultural objects modulate reward circuitry	(Erk et al., 2002)	442
Neural Correlates of Behavioral Preference for Culturally Familiar Drinks	(McClure et al., 2004)	1519
Nonlinear responses within the medial prefrontal cortex reveal when specific implicit information influences economic decision making.	(Deppe et al., 2005)	333
A Functional Magnetic Resonance Imaging Study of Neural Dissociations between Brand and Person Judgments	(Yoon et al., 2006)	339
Neural Predictors of Purchases	(Knutson et al., 2007)	1219
Neuromarketing: a layman's look at neuroscience and its potential application to marketing practice	(Fugate, 2007)	290
A current overview of consumer neuroscience	(Hubert & Kenning, 2008)	336
Marketing actions can modulate neural representations of experienced pleasantness	(Plassmann et al., 2008)	1112
Neuroethics of neuromarketing	(Murphy et al., 2008)	258
Changes in Brain Activity During the Observation of TV Commercials by Using EEG, GSR and HR Measurements	(Vecchiato et al., 2010)	163

Source: own elaboration.

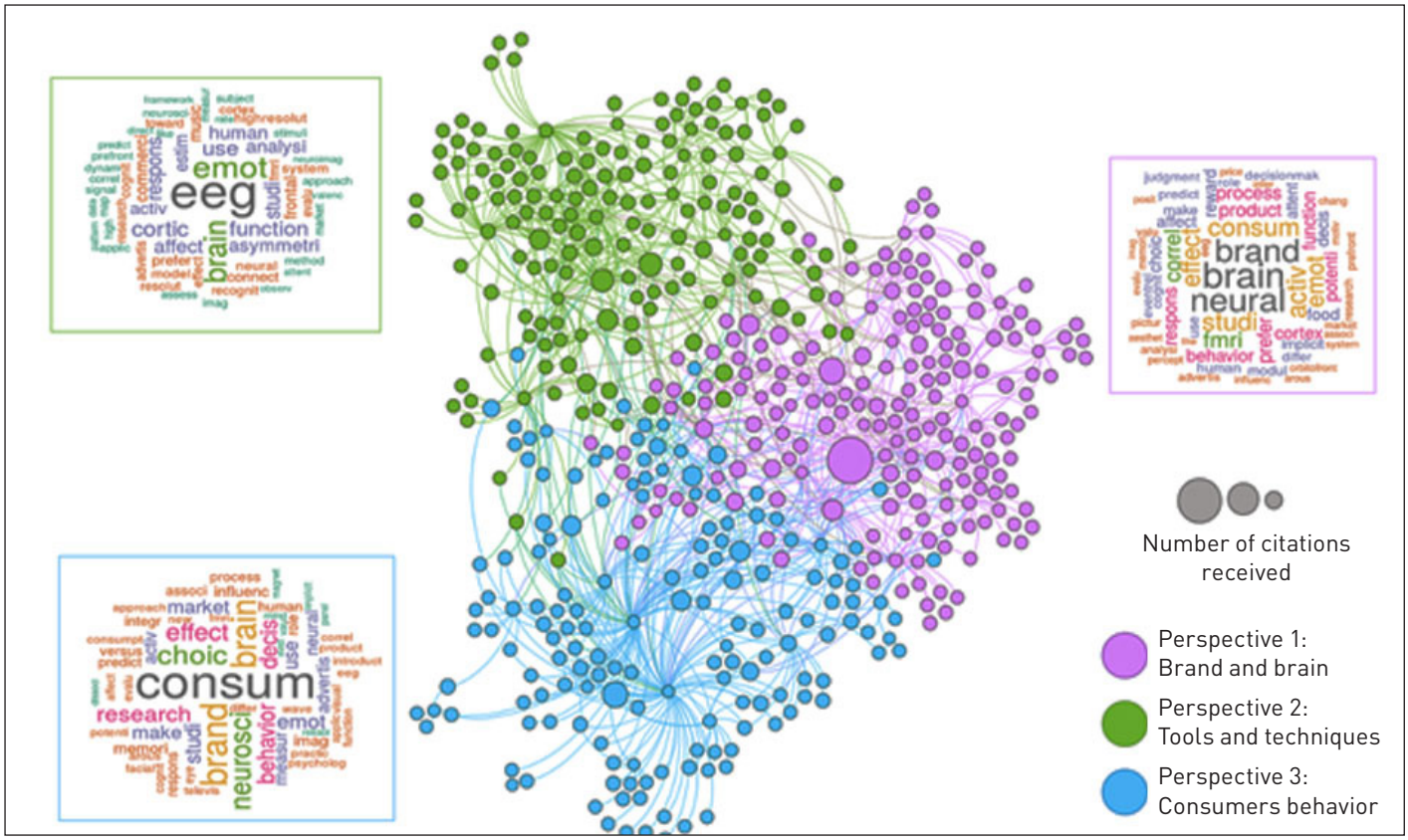

Figure 4. Neuromarketing network
Source: own elaboration.

4.5 Experimental research

Research in this category is done to evaluate brain activity by using techniques from neuroscience, such as fMRI (Functional Magnetic Resonance Imaging), NMR (Nuclear Magnetic Resonance), HR (Heart Rate), EEG (Electroencephalography) scans and GSR (Galvanic Skin Response). Linear regression models are the most used quantitative technique to process information.

Two of the most relevant documents within the hegemonic category are "Neural Correlates of Behavioral Preference for Culturally Familiar Drinks" and "Neural Predictors of Purchases." The former attempts to identify the influence of brand image on choices, behaviors and brain responses of Coca-Cola and Pepsi consumers; it concludes that the Coca-Cola brand has a significant influence on the preferences expressed by consumers and, more importantly, on their brain responses. The latter determines the response of different neuronal circuits to the preference of a product against excessive prices; it suggests that the activation of different circuits related to the anticipatory effect precedes and supports consumers' purchase decisions.

Erk et al. (2002) showed that artificial cultural objects (vehicles with different characteristics), categorized by the income and social classification of each segment, activate areas of the brain related to reward. Likewise, Deppe et al. (2005) studied through fMRI the way in which economic decisions are influenced by implicit memory. In the case of products that are more differentiated by the information that the consumer has about the brand, the brain shows less activity in the areas related to working memory and reasoning when comparing favorite brands with others. In contrast, the areas related to emotions demonstrate a higher degree of activity.

Later, Yoon et al. (2006) used fMRI methods to study if implicit (and often explicit) assumptions regarding product and brand qualities are processed in a similar manner to those about people; and found evidence to the contrary. Kenning and Plassmann (2008) verified how consumer satisfaction in neural terms is affected by the types of marketing and price changes of a product, with the authors suggesting that the brain calculates the satisfaction experienced through the integration of actual sensory properties and product expectations. Finally, Vecchiato et al. (2010) analyzed brain activity during the observation of commercials; they found that advertising considered pleasant increased activity in the left hemisphere of the brain.

Despite the use of tools from neuroscience, it is evident that development achieved in the field is not conclusive, and the experiments carried out thus far are only superficial approximations that do not yet allow us to understand what happens in the brain of the consumer.

4.6 Structural documents

Structural documents have the highest rate of centrality (they quote hegemonic documents and at the same time they are quoted by recent publications), which implies that they connect the whole network. The articles in this category deal mostly with experimental research that seeks to understand and identify how the brain and its different areas are affected by stimuli (Table 5).

The first paper in this category was authored by Lee et al. (2007) who mapped neuroscience techniques that can be used as a basis for research of marketing issues such as trust, pricing, and society-related marketing (ethics). The authors suggest that neuroscience can help us to understand how humans create, store, remember, and relate to brands. Within this theoretical avenue of enquiry, Kenning and Linzmajer (2011) do not use the concept of neuromarketing, they rather refer to consumer neuroscience and consider it a sub-discipline of neuroeconomics. They also believe that this area of knowledge is still an incipient discipline that requires more exhaustive tests and robust theoretical debate.

Wilson et al. (2008) focus on analyzing the ethical issues involving consumer awareness, consent and understanding, and discuss the models of persuasion employed by marketing. They believe that neuromarketing should be used to help people understand what they really want and not against them, what they refer to as "ethical marketing strategies".

Later, Astolfi et al. (2008) determined through various experiments using EEG tests that the parietal areas of the brain play an important role in relation to the flow of information during the observation of television commercials. These areas show greater activity when the subjects are exposed to commercials that have been recalled sometime after their observation. Likewise, Ohme et al. (2010) propose that the measurement of activity in the frontal lobe can be a diagnostic tool to help determine the potential of television commercials. Guixeres et al. (2017) established that aspects related to the impact of advertising and its propensity to be recalled can be detected. In their experiment they found a significant correlation between neuroscience metrics and the effectiveness of advertisements on a YouTube channel.

Subsequently, Ariely and Berns (2010) and Ohme et al. (2010) addressed the importance of using neuroscience tools and techniques in marketing processes, especially in market research, to evaluate or design products or as part of the development of advertising campaigns. In addition, Plassmann et al. (2012) proposed that consumer neuroscience can make a substantial contribution to brand positioning research with respect to psychology as a tool for observing the mental process in greater depth.

Kenning and Linzmajer (2011) presented an overview of consumer neuroscience studies, verified methods, findings and implications, and categorized research in relation to its purpose (Product Policy, Pricing Policy, Communication Policy, Distribution Policy, Brand Research). Other authors, such as Venkatraman et al. (2012) and Solnais et al. (2013) consider that neuroscience techniques and tools do not replace current methods applied in marketing practice, and propose that these new procedures be seen as complementary to understanding consumer behavior.

4.7 Recent documents

These documents make reference to both classical and structural studies to give them support, structure and form. They have the least number of entries, or no entries at all. However, their contribution is fundamental to the development of new theories that demonstrate the advancement and evolution in this field, as well as playing an indispensable role in the current and future application of new non-conventional methods explained in three different perspectives (Table 6).

The authors (Vecchiato et al., 2011a; Vecchiato et al., 2014a; Cartocci et al., 2017) focus their studies on the application of neuromarketing in the advertising industry, considering cultural and gender factors and reactions to public service content through the EEG method. Other authors incline their research towards a

more cognitive perspective linked to psychology in order to better understand the functioning of the brain with branded and even latent stimuli which are influenced by gender differences (Kim, Kim, Han, Lim, & Im, 2016; Fehse, Simmank, Gutyrchik, & Sztrókay-Gaul, 2017; Hsu & Cheng, 2018; Ramsøy, Skov, Christensen, & Stahlhut, 2018; Ma, Zhang, & Wang, 2018).

There is also a study by Crespo-Pereira and Legerén-Lago (2018) that reviews theories developed from the application of neuromarketing in the audiovisual industry, and the impact that it could have for the development of new content with these characteristics.

Harris et al. (2018), Jiménez and Zambrano (2018), Gani et al. (2018), and Lim (2018) explore the existing alternatives provided by neuromarketing that contribute to current and future theory and practice in different business processes, which also represent lower costs and are more advanced tools.

The perspectives that delve deeper into the three categories identified through the application of the clustering algorithm (Figure 4) are notable. Within these groups, the most outstanding authors in the field of research are still the same, *i.e.*, Plassman, Cartocci, Vecchiato, Astolfi and Ma Qg. This will be later discussed in detail.

4.8 Perspective 1: brain and brand

Initial studies in the field of neuroscience highlight that activation of the ventromedial prefrontal cortex is critical for preference trials (Paulus & Frank, 2003). In the same line of research, McClure et al. (2004) and Stoll, Baecke, and Kenning (2008) state "what you see is what you get", for which a functional MRI study on neuronal correlates focused on attractive packaging was conducted. In contrast, Plassmann et al. (2008) conducted a study on how marketing actions can modulate the neuronal representations of pleasure. These researchers also focus on more cognitive-oriented studies, such as a paper by Klucharev, Smidts and Fernández (2008) that mentions the "expert power" that marketing can have as a persuasive mechanism. Tusche, Bode and Haynes (2010) suggest that consumer choices can be predicted through certain neural responses.

Authors like Reimann, Zaichkowsky, Neuhaus, Bender, and Weber (2010) present the design of a package that gathers behavioral, neuronal and psychological research, which they call an "aesthetic package". Regarding the fMRI method, Venkatraman et al. (2012) present their perspectives on branding, propose new data for marketers of branding through scanning, and suggest that neuroscience is an effective tool for understanding brand preferences. An exploratory study by Al-Kwifi (2016) that uses high-tech products suggests that fMRI can play a key role in detecting attitudes towards brand change by focusing on new brands versus known brands analyzed in the field of neurophysiology, response latency, and choice.

With respect to the most current research, we found one paper by Fehse et al. (2017) which, by means of the fMRI method, studies the perception of the elements involving different functional pathways on organic or popular brands. Furthermore, Goto et al. (2017) show that the neural signals of selective attention are modulated by subjective preferences and purchase decisions in a virtual shopping task. In a more practical study, Ma et al. (2018) analyze how the effect of continuous gain influences consumer price perception, an ERP (Event-Related Potential) study.

4.9 Perspective 2: tools and techniques

Authors such as Davidson and Irwin (1999) indicate that the neuronal responses of the prefrontal cortex, more specifically of the ventromedial and dorsolateral zones, are the representation of positive and negative elemental states. Aftanas, Reva, Varlamov, Pavlov, and Makhnev (2004) used the EEG method with an experimental sample of 20 right-handed subjects to evaluate the (emotional) brain activity that occurs during the application of a stimulus; the results showed that there is synchronization of the right hemisphere in posterior areas and desynchronization in the left hemisphere in anterior areas. Likewise, Astolfi et al. (2007a) reaffirm that the use of the EEG and fMRI methods allow us to observe the cortical activity of the brain; they argue that with these tools and techniques, it is possible to identify patterns of functional connectivity that are given by the experimental conditions.

In a subsequent study, Astolfi et al. (2008) focused their research on cortical activity in order to obtain information on recall through the EEG method. They exposed a group of people to TV commercials, evaluating after a couple of days how many were recalled and how many were forgotten.

A similar experiment was devised by Vecchiato et al. (2011b), who analyzed changes in brain activity during the observation of video clips, with the objective of observing asymmetry in frontal EEG activity with respect to the distribution of information from pleasant and unpleasant commercials. Later, Vecchiato et al. (2014b) proposed a new study in which they administered two tests to a group of people during the observation of television commercials. In both tests, the researchers used three neuronal measurement tools: EEG, GSR and HR; in the first test the information presented pleasant stimuli, while the second test showed results of emotional responses. They concluded that this technology could be useful for marketing specialists. Guixeres et al. (2017) carried out an experiment to evaluate the neurophysiological responses (variability of heart activity, neuronal responses and eye tracking) of thirty-five participants who watched eight commercials. The results obtained can be applied in the creation, improvement, and development of digital advertising content.

Table 5. Structural documents

Document	Objective	Type of research	Reference
What is 'Neuromarketing'? A discussion and agenda for future research	To theoretically extend the scope of Neuromarketing beyond its commercial application and into consumer behavior in a conceptualization of marketing science; that also encompasses neuroscience and macroeconomics	Theoretical	(Lee et al., 2007)
Neural basis for brain responses to TV commercials: A high-resolution EEG study	To investigate the brain activity that occurs during the observation of TV commercials by monitoring cortical activity and changes in functional connectivity in normal subjects	Experimental	(Astolfi et al., 2008)
Neuromarketing and Consumer Free Will.: Business Source	To examine the impact of neuroscience discoveries and methods on marketing practices, within the exercise of individual free will	Experimental	(Wilson, Gaines, & Hill, 2008)
Application of frontal EEG asymmetry to advertising research	Identify areas of the prefrontal cortex that are activated in reaction to T.V. ads	Experimental	(Ohme, Reykowska, Wiener, & Choromanska, 2010)
Neuromarketing: the hope and hype of neuroimaging in business	Explain how neuroimaging methods and techniques are used to analyze consumer product choice	Experimental	(Ariely & Berns, 2010)
Consumer neuroscience: an overview of an emerging discipline with implications for consumer policy	analyze different methods, findings and implications of studies associated with consumer neuroscience.	Theoretical	(Kenning & Linzmajer, 2011)
New scanner data for brand marketers: How neuroscience can help better understand differences in brand preferences	Make use of effective segmentation to be able to divide the population into different groups that provide information of different needs in order to better understand the buyer's decision making and thus help improve the seller's methods	Experimental	(Venkatraman, Clithero, Fitzsimons, & Huettel, 2012)
Branding the brain: A critical review and outlook	demonstrate a current and previous overview of the application of neuroscience to consumer psychology particularly to brand positioning	Experimental	(Plassmann et al., 2012)
Consumer neuroscience: Assessing the brain response to marketing stimuli using electroencephalogram (EEG) and eye tracking	suggest a method for the design and presentation of products more compatible with consumer preferences	Experimental	(Khushaba et al., 2013)
The contribution of neuroscience to consumer research: A conceptual framework and empirical review	propose an approach to the classification of findings, which will facilitate the evaluation of evidence around issues of decision-making, rewards, memory and emotions	Experimental	(Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013)
Consumer Neuroscience-Based Metrics Predict Recall, Liking and Viewing Rates in Online Advertising	Determine the effectiveness of advertisements on digital channels (YouTube) using neuroscience-based metrics	Experimental	(Guixeres et al., 2017)

Source: own elaboration.

Gupta et al. (2016) performed an analysis of different EEG tests and suggested a method different from the traditional one, which they consider more effective in the evaluation of three emotions: valence, dominance, and excitement. These authors also presented a subjective classification of taste and found a better characterization of human active states during the observation of a video clip.

Additionally, Kim et al. (2016) proposed the use of different tools to measure physiological changes in consumers. These authors evaluated changes in oxyhemoglobin concentrations by means of an NIR spectroscopy system. Based on a set of Public Service Announcements (PSA), Cartocci et al. (2017) developed a seventeen-year study in the USA and Europe on anti-smoking advertising campaigns, proposing a method based on EEG, GSR and HR tests to evaluate the effectiveness of these campaigns. Later, Borghini et al. (2017) conducted a study along similar lines in order to bring the analysis of mental and emotional states closer to reality, moving from BCI (brain/computer interface) technology to passive BCI.

4.10 Perspective 3: consumer behavior

This perspective analyzes the emergence of neuromarketing as a complementary technique to traditional marketing, with the objective of understanding consumer behavior. Some authors (Telpaz, Webb, & Levy, 2015; Plassmann et al., 2015) consider that although traditional methods have limitations in understanding consumers, this does not mean that some methods should replace others in the case of those used by neuroscience; on the contrary, they can complement each other.

Yoon et al. (2012) indicate that neuroscience will enable the shaping of new models to explain how consumers make decisions, involving variables that are often not considered, for example physiological (hunger, stress, social influence) and neural. Meanwhile, Plassmann et al. (2015) propose that the usefulness of consumer

neuroscience research (applied in the field of marketing) will be more widely accepted when it provides valid and reliable information that cannot be obtained using traditional methods to understand consumer behavior. Finally, based on previous studies, Hsu (2017) states that the methods applied in neuroscience allow for a deeper approach to thoughts, feelings and intentions, something that traditional methods cannot do. However, he agrees with the complementarity between both methods rather than with substitution.

Consumer neuroscience also allows for the evaluation of advertising content, such as a study by Utkutug-Bozoklu and Alki´bay (2016) in which, through an experiment, they analyzed the effectiveness of the strategies used and their impact on consumer memory. They confirmed that elements such as music, humor and emotion are specific to advertisements that are key to creating advertising memory.

Braeutigam, Lee and Senior (2019) propose that consumer neuroscience should move away from the reactive view they currently offer of consumer behavior, as this approach presents a partial understanding of the functioning of the brain which is somewhat removed from reality. It should seek a more dynamic view of neuronal behavior as brain activity is more spontaneous and not always the result of stimuli (Lee et al., 2018). Current methods denote a more marked inclination towards non-conventional procedures to make more in-depth evaluations, therefore, it is worth investing time in more rigorous research to strengthen knowledge in this area.

As stated in the previous paragraphs, one of the most relevant avenues of research in consumer neuroscience is the analysis of consumer behavior. However, it is clear that it still requires extensive exploration to allow for the construction of theory on the subject. As Yoon et al. (2012, p.485) indicate "There is no magic: one cannot look inside the head of a decision maker and predict the individual selection of toothpaste or tomorrow's visit to the grocery store."

5. Conclusions

The literature found on neuromarketing is fragmented and lacks clear guidance on what defines research in the area; the lack of standards does not allow a distinction between what research with acceptable rigor is and what it is not (Lee et al., 2018) despite the fact that few pieces of research have generated rigorous and valid empirical findings (Lim, 2018). Consumer neuroscience is a relatively young field, and in its first years pioneering work has been generated on the identification of neuronal processes linked to decision making (Plassmann et al., 2015). However, a discussion about the reliability, validity and replicability of findings remains necessary; several authors consider that neuromarketing is at an early stage and the research community should be cautious about claims and rushed generalizations (Varan, Lang, Barwise, Weber, & Bellman, 2015). Critical discussion about what neuromarketing actually represents and what it has done as a sub-area of marketing should be carried out (Lee et al., 2018); its implications, particularly the ethical aspects of this emerging field, should be analyzed (Ulman, Cakar, & Yildiz, 2015).

In general terms, the contributions made by the authors considered hegemonic in consumer neuroscience could be classified into two groups. The first is made up of practical contributions in which the authors sought new techniques to try to understand consumer behavior. To this end, they relied on a field of study not linked to business management, but to the areas of health and medical sciences (in the case of neuroscience). The second group is made up of theoretical contributions in which the first steps are taken in the conceptual development of this field.

Research in the category of structural documents applies different techniques generally employed in neuroscience and employs experiments that allow scholars to determine how the consumer and his or her brain react to different stimuli. Thanks to the connection between neuroscience and consumer psychology, the former area obtains more in-depth information and there is an emergence of methods and assumptions to evaluate the neuronal responses of consumers' exposure to stimuli.

Recent research seeks to evaluate the models and assumptions proposed by hegemonic and structural authors through the development of experiments carried out in different industries, sectors, and client segments.

Consumer neuroscience borrows a number of tools and techniques from other fields, *e.g.*, fMRI, EEG, and Eye Tracking. fMRI is a technique based on radiation that produces high-resolution images to measure changes in cerebral blood flow during the stimulation of visual activity; EEG detects and records patterns of brain activity, and Eye Tracking is a recent tool based on ocular responses during exposure to a visual element (image, video, etc.).

The bibliometric comparison of scientific production associated with neuromarketing in the Scopus and WoS databases showed that there are some authors in common between these databases. However, in Scopus they are more prominent due to their high number of publications and h-index. The search shows that there is a difference between both databases in terms of the number of publications. Scopus contains 63% of the total records and it is not possible to indicate degrees of importance among them, but rather a relationship of complementarity. The most relevant authors in relation to the number of publications and h-index are Babiloni F., Vecchiato G. and Astolfi L. The regions with the highest production are the USA and Spain. Publications are still mainly found in specialized journals in fields other than marketing, such as psychology, neuroscience, and computer science. It is worth mentioning that the topics related to the area of neuromarketing are attracting more and more attention from the scientific community, this is demonstrated through the growth curve of production in the area.

Table 6. Recent documents

Document	Objective	Design and type of research	Reference
On the Use of EEG or MEG Brain Imaging Tools in Neuromarketing Research	To analyze the cultural differences between the production of commercial videos for carbonated beverages in Western and Eastern countries.	Experimental (Mixed)	(Vecchiato et al., 2011a)
Neurophysiological Tools to Investigate Consumer's Gender Differences during the Observation of TV Commercials	Analyze the perception of TV ads and differentiate their production according to the consumer's gender.	Experimental (Mixed)	(Vecchiato et al., 2014b)
Estimating Consumer's Subjective Preference Using Functional Near-infrared Spectroscopy: A Feasibility Study	Analyze the participants and their changes in oxyhemoglobin concentrations using a NIR spectroscopy system	Experimental (quantitative)	(Kim, Kim, Han, Lim, & Im, 2016)
Organic or popular brands—food perception engages distinct functional pathways. An fMRI study	Search for neural correlates of the differences in psychological added value of organic food brands and popular food brands.	Experimental (quantitative)	(Fehse, Simmank, Gutyrchik, & Sztrókay-Gaul, 2017)
Electroencephalographic, Heart Rate, and Galvanic Skin Response Assessment for an Advertising Perception Study: Application to Antismoking Public Service Announcements	The aim of this protocol is to apply electroencephalography (EEG) and autonomic signal analysis to study responses to anti-smoking PSAs.	Non - Experimental (quantitative)	(Cartocci et al., 2017)
Welcome to the jungle! The Neuromarketing literature through the eyes of a newcomer	Examine whether the existing body of Neuromarketing literature can support such growth within the parameters of the field.	Experimental (quantitative)	(Lee et al., 2018)
Consumer neuroscience for marketing researchers	Identify in previous studies which are those different techniques more effective, advanced and of less cost to the fMRI that are applied in the consumer neuromarketing	Documentary review	(Harris, Ciorciari, & Gountas, 2018)
fMRI Neuromarketing and consumer learning theory	To examine the impact of gender on the neural substrates of consumer behavior theories	Experimental (quantitative: Hypothesis Evaluation)	(Hsu & Cheng, 2018)
Frontal Brain Asymmetry and Willingness to Pay	To identify whether or not the specific brain activation and asymmetry in prefrontal cortex involvement would be related to consumer choice.	Experimental (Mixed)	(Ramsøy, Skov, Christensen, & Stahlhut, 2018)
"You Win, You Buy" – How Continuous Win Effect Influence Consumers' Price Perception: An ERP Study	Determine whether emotional arousal would affect consumers' price perceptions and willingness to buy.	Experimental (quantitative)	(Ma, Zhang, & Wang, 2018)
El uso de la Neurociencia en el diseño de contenidos transmedia en los canales de televisión públicos de Europa: Videojuegos y Social TV	Analyze how neuroscience can be used for the design of products such as video games and television.	Documentary review	(Crespo-Pereira & Legerén-Lago, 2018)
Marketing sensorial: merchandising a través de las emociones en el punto de venta. Análisis de un caso	Review the implementation of a series of sensory marketing techniques in the case of a Spanish textile company	Experimental (quantitative)	(Jiménez & Zambrano, 2018)
Challenges and prospects of neuromarketing: Bangladesh perspective	Explore the challenges, perspectives, limitations and potential of practicing neuromarketing in the context of Bangladesh as a cutting edge marketing issue in order to provide recommendations accordingly.	Experimental (quantitative)	(Gani et al., 2018)
Demystifying neuromarketing	To contribute to the theory and practice of marketing through the analysis of the potential of neuromarketing.	Theoretical (qualitative)	(Lim, 2018)

Source: own elaboration.

Due to the early stage of development of neuromarketing, it is common to find diverse detractors. However, as concepts and constructs are studied in detail, and tools and techniques are validated, many doubts about the subject will be settled. Moreover, it is necessary to clarify that the objective of neuroscience applied to marketing is not to replace traditional methods but rather to complement them.

For future research, it is necessary to develop experiments with solid scientific rigor that allow the validation or refutation of the findings that have been reported to date; thus conceptual generalization and the construction of theory in consumer neuroscience may be achieved. Neuroscientists are also required to accompany researchers in the area of marketing in order for research to become more comprehensive

and coherent. Another associated difficulty is that most studies are private and, therefore, companies do not provide information from these studies. The advance of neuroscience means that the understanding of decision-making and consumption processes can be more holistically explained; it is there where the great challenge lies, to finally understand why people select, consume, and buy the way they do.

Conflict of interest

The authors declare no conflict of interest.

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