

The application of neuromarketing tools in communication research: A comprehensive review of trends

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Abstract

This study provides an overview of the evolution of the body of knowledge, current research streams, potential new domains, and theoretical models of interest for neuromarketing research developed in the field of communication. Neuromarketing is defined here as research applying psychophysiological or neuroscience methods in communication. We particularly implemented a comprehensive analysis of 861 publications using keyword cooccurrence analysis and science mapping tools. The performance analysis shows a strong growth in the number of publications over the last decade, with a slight declining impact in terms of citations after reaching a peak around the turn of the century. Contributions published in journals in business and communication fields (and not psychology or neuroimaging) are those with the largest average citations per year. The evolution diagrams highlight that the use of brain imaging tools to study ad persuasion in virtual environments and social marketing contexts (e.g., health or sustainable communication), as well as the employment of novel metrics (neural synchronization) and deep learning methods to analyze data, constitute fruitful research streams in the application of neuromarketing tools in communication research. These results offer communication scholars an accurate insight on recent scientific research applying neuromarketing that can shape further studies.

KEYWORDS

advertising, communication, comprehensive analysis, consumer neuroscience, literature review, neuromarketing, persuasion

1 | INTRODUCTION

In 2022, firms worldwide spent USD 793.25 billion on digital, magazine, newspaper, out-of-home, radio, and TV advertising (Statista, 2023). Governments and public institutions also devoted a huge amount of their budgets to communication campaigns. For-

profit businesses, NGOs, public administrations, and political parties are interested in ensuring that every dollar invested in their communication strategies has the expected outcomes, whether in terms of attention, recall, click-through, product purchase, or even citizen behavioral changes. This increasing spending on communication, coupled with the hundreds of advertisements competing for

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audience interest, has made it crucial for institutions to make a greater effort in selecting the most persuasive media features in their messages. Broadly speaking, a communication element is considered persuasive when it provokes changes in preferences or behaviors in message receivers conforming to active attempts by a communicator to boost such changes (Falk & Scholz, 2018).

Professional experts and communication academics have traditionally turned to self-reporting tools (questionnaires, focus groups, or interviews) to assess message persuasion, as well as to understand or forecast consumer behavior after being exposed to messages (Agnihotri et al., 2022; Detweiler et al., 1999). These conventional methods have been shown to be accessible, easy to use and cost-effective in measuring consumer attitudes, intentions, and thoughts (Harris et al., 2018). Nevertheless, self-reports may be subject to social desirability, useless in evaluating sensitive topics (e.g., sexual or political orientations) or not be able to assess continuous consumer reactions during message exposure (Casado-Aranda, Sánchez-Fernández, et al., 2022). Indeed, it may be that attitudes, intentions, or self-reported ad persuasion do not fully explain audience behavioral changes resulting from a communication campaign, as there may be additional lower-order cognitive and affective mechanisms in play during message exposure, which may be decisive when it comes to ad outcomes (Weber et al., 2015). Consequently, there was a call for complementary methods that fully monitor moment-by-moment consumer reactions during the evaluation of communication campaigns.

Aware of the shortcomings of traditional methods, in the late 1990s, communication scholars began to use tools and theories borrowed from psychology, physiology, and neuroscience to evaluate the cognitive and affective responses elicited by different types of messages (Lang et al., 1995). This was the genesis of what we know today as neuromarketing or consumer neuroscience, “which applies tools and theories from neuroscience to better understand decision making and related processes” (Plassmann et al., 2012, p. 427). Here we set out to study the application of these tools in communication research by means of a comprehensive and bibliometric study.

Although several bibliometric studies have been published recently on consumer neuroscience (e.g., Alsharif et al., 2021; Kansra et al., 2023; Siddique et al., 2022; Zhu et al., 2022), our study differs in two important ways. First, we concentrate specifically on the subfield of marketing communications. Second, unlike prior studies as those by Sánchez-Fernández et al. (2021) we explore the contributions in communication research that have used not only neuroimaging tools such as EEG and fMRI, but also psychophysiological methods such as eye-tracking and skin conductance. The current bibliometric study thus contributes by presenting a comprehensive account of developments and trends of applying neuromarketing methods in communication research.

Since its origin, several tools have been used to identify the cognitive-affective mechanisms involved in the processing of marketing stimuli in general and communication in particular. Supporting Information: Material 1 includes a description of the most relevant tools employed in the field of neuromarketing. The psychophysiological methods we focus on in this paper are skin

conductance, facial electromyography, face reading, heart rate, and eye-tracking. The neuroimaging tools include EEG, fMRI, and fNIRS.

2 | THE CURRENT RESEARCH

Since the late 1990s, psychophysiological and neuroimaging tools have been applied to explore message persuasion in a wide range of communication contexts, as well as a great diversity of message frames and research disciplines. Consequently, it would be academically stimulating to step back and reflect on the evolution of the scientific production, authors and sources, current streams, and potential domains of interest for neuromarketing academics interested in communication research. This paper aims to fill this research gap using a bibliometric and comprehensive review of the application of neuromarketing methods in communication research. To that end, we propose the following research questions (RQs):

- RQ1: What has been the growth of publications applying neuromarketing methods in communication research as indexed in the Web of Science (WoS) database?
- RQ2: What are the top journals, authors, publications, and tools worth considering in future studies of applying neuromarketing methods in the communication discipline?
- RQ3: What are the most prolific theoretical approaches and models in communication research using neuromarketing methods?
- RQ4: What are the most crucial research avenues based on the conceptual structure of scientific research in communication, that is, what are the main emerging and declining themes and subthemes of communication research by means of neuromarketing methods?

To address these RQs, this paper is structured as follows: In Section 3, we characterize the methodology and research design. Then, in Section 4, we discuss our findings regarding performance and themes, including a wordcloud, a so-called alluvial diagram, keyword cooccurrence, and theoretical models used in the literature. Finally, in Sections 5 and 6, we highlight the contributions and main limitations of the study.

3 | METHODS

For data collection, we adopted the PRISMA approach (see Page et al., 2021), a widely accepted framework used in systematic reviews and meta-analyses of marketing literature (Paul & Barari, 2022). Particularly, for the current review, we carried out a query on April 17, 2023 on the WoS database and considered all publications to date about the application of neuromarketing methods in communication research. The specific consultation was as follows:

(TS= [“consumer neuroscience” OR neuromarketing OR “fMRI” OR “EEG” OR “eye-tracking” OR “fNIRS” OR “skin conductance” OR “electromyography” OR “heart rate” OR “facial expression*”]) AND TS= (“persuasion” OR “message” OR “advertising” OR “communication effectiveness”) and Article (Document Types). TS searches for topics in title, abstract, author keywords, and keyword Plus. A flow

chart indicating each step for identifying articles based on PRISMA is included in Supporting Information: Material 2.

After restricting to articles written in English without a timeframe limit, we discarded documents unrelated to marketing communication. The search revealed 861 publications. All the analyses shown below were carried out with the open-source package R Bibliometrix (Aria & Cuccurullo, 2017). In particular, network tools to visualize and explore data in both performance analysis and scientific mapping were used with the aim of analyzing the conceptual structure of the research field (Aria & Cuccurullo, 2017). More specifically, we employed a bibliometric approach, which provided an objective analysis based on statistical techniques. It allowed to develop both basic and advanced analyses of the large volume of articles published in the journals in the field of neuromarketing and communication. Following Cobo et al. (2011), the key procedures usually applied in bibliometric studies are performance or output analysis and the so-called scientific mapping method. The former aims to assess the productivity and popularity of different agents based on bibliographic data. The latter seeks to highlight the structural and cognitive patterns of the discipline by visualizing the main themes in a synchronic perspective based on a co-citation keyword. That is, each scientific field is characterized by a set of keywords assigned by authors to publications or by citation indexes. From this set of keywords and their representation in the form of a network of cooccurrence of terms, it is possible to represent the knowledge base incorporated into the database and to explore the level of development and relevance of the different themes.

4 | ANALYSIS AND FINDINGS

4.1 | Performance analysis

4.1.1 | Overview

Table 1 shows an overview of the analysis developed in Bibliometrix as implemented in R Studio. Results show that the average age of articles is 6.45 years. On average, studies have been cited 19 times and were mostly written by 4 researchers. Only 1 in 4 articles analyzed were developed by an international team of scholars, which represents a low rate of collaboration when compared with other topics such as business management (Mesquita et al., 2022). Furthermore, it worth highlighting that the 861 studies were published in 399 sources, thus showing that the field is quite scattered.

As displayed in Figure 1, an average of 18.5 contributions were published per year, with a substantial increase starting in 2016, after which, on average, 81 studies were released per year. This very strong growth in the number of studies since the second decade of the 2000s may be due to factors such as the launch of open access journals (e.g., Frontiers) and the start of the application of neuroimaging in the field of communication (see also Figure 2). The yearly average number of times a manuscript has been cited reached a peak in 1999–2003 (6.35 citations/manuscript per year) in contrast to 2005 (1.25 citations/manuscript per year). Despite the number of

TABLE 1 Main features of the review.

Characteristics of the analysis	Results
Main information about the data	
Timespan	1979–2022
Documents	861
Sources	399
Annual growth rate (%)	7.05
Document average age	6.45
Average citations per doc	19.3
References	35.749
Document contents	
Authors' keywords	2.354
Authors	
Total number of authors	2.704
Authors of single-authored docs	70
Coauthors per doc	3.83
International coauthorships (%)	24.97

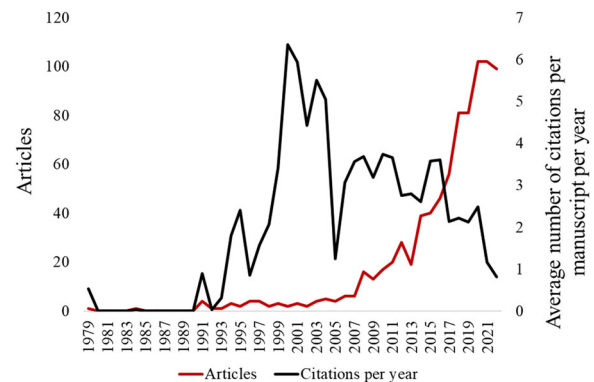


FIGURE 1 Annual scientific production on neuromarketing methods in communication research and average number of citations per year.

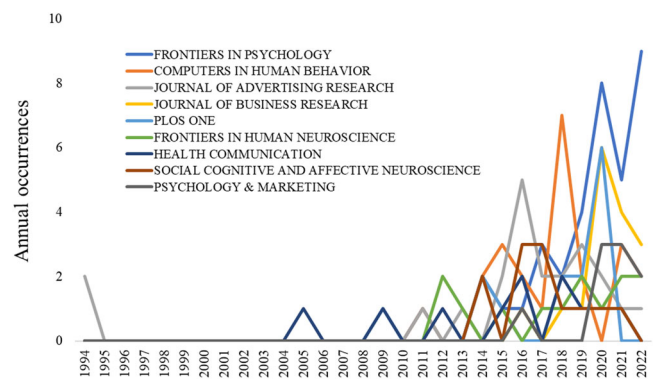


FIGURE 2 Evolution of annual scientific production on neuromarketing and communication published in the most prolific sources.

citations increasing from that point onwards it has not been able to reach the figures of 2000. Consequently, whereas an upward trend is evident in the number of published articles, a downward tendency can be seen in the number of citations per article. Furthermore, it should be noted that 45.64% of the articles (almost half of them) have been published in open-access journals.

4.1.2 | Most relevant sources and authors in the application of neuromarketing tools in communication research

The 861 peer-reviewed articles cover publications in journals of 4 major disciplinary backgrounds: business (24.75%), communication (24.08%), neuroscience (15%), and psychology (including journals in multidisciplinary, experimental, and general psychology; 28.45%). The remaining research belongs to a wide range of scientific areas, from management and computer science information systems to behavioral sciences. In particular, the journal *Frontiers in Psychology* is the source that has published the largest number of scientific papers on neuromarketing and communication (36 articles). In the communication and business disciplines, the *Journal of Advertising Research* (22 articles), the *Journal of Business Research* (16 articles), *Health Communication* (16 articles), the *Journal of Advertising* (11), *Psychology and Marketing* (11), and the *International Journal of Advertising* (10) stand out. Furthermore, the *Frontiers in Human Neuroscience* (14), *PLOS One* (15), and *Social Cognitive and Affective Neuroscience* (12) sources contributed to the field of neuroscience to the greatest extent. Figure 2 shows that the application of neuromarketing tools to communication research has attracted the greatest interest in the last 4 years, mainly in 2 psychology/neuroscience journals (*Frontiers in Psychology* and *PLOS One*) and

2 business and communication sources (*Journal of Business Research* and *Journal of Advertising*).

However, when considering the average number of citations received by each article within the source (i.e., number of citations/number of articles), the findings show that the journals with the highest impact belong mostly to the field of business and communication. Particularly, together with the neuroscience-related journals of *Neuroimage* and *Social Cognitive and Affective Neuroscience*, the *Journal of Marketing Research*, *International Journal of Research in Marketing*, *Journal of Interactive Marketing*, and *Journal of Advertising* stand out as the most relevant outlets. In turn, scientific journals such as *Frontiers in Psychology*, *Frontiers in Neuroscience*, or the *IEEE Access*, despite having a high number of publications, receive the lowest impact per article (Figure 3).

It is furthermore worth noting some of the most productive authors in the field (see Figure 4). For example, Falk and coauthors (amongst which O'Donnell), who belong to the Communication Neuroscience Lab at the Annenberg School of Communication (University of Pennsylvania), constitute highly productive authors in the application of neuroimaging (fMRI mainly) in (health) communication research. Also, coauthors Pieters (Tilburg University) and Wedel (University of Maryland) are prolific scholars in the use of eye-tracking in communication contexts. Figure 4 is quite revealing, as it summarizes the dynamics of publications from the most productive authors in the field. The intensity of the blue color refers to the number of citations per year, and the size of the circle refers to the number of articles published. It can be observed, for example, that whereas the authors Pieters and Wedel consistently published around 2–3 articles per year on eye-tracking with a high number of citations in the first decade of analysis, they published only a few papers on this topic over the last 11 years. They can be labeled as the pioneers in the communication field with the application of eye-

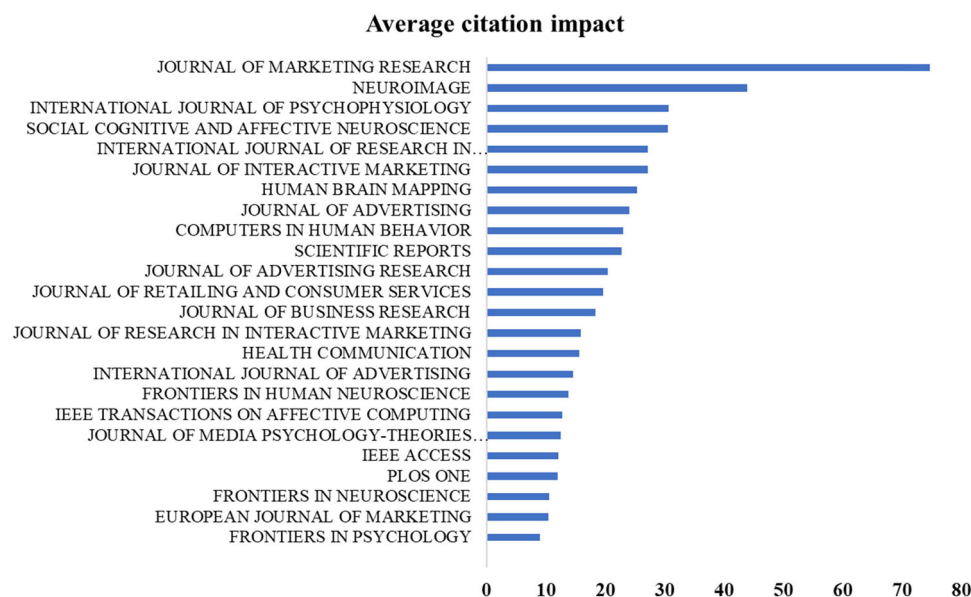


FIGURE 3 Average citation impact of the main outlets publishing contributions applying neuromarketing tools in communication research.

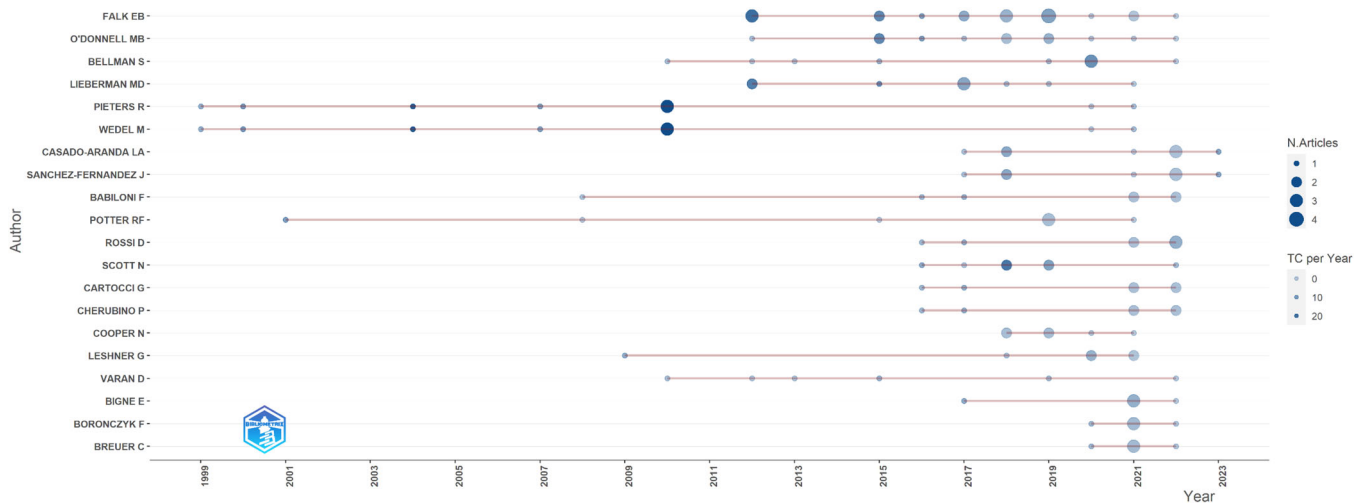


FIGURE 4 Evolution of the scientific production of the most productive authors in the period analyzed.

tracking. The scholars Falk and O'Donnell, in turn, started publishing papers on neuroimaging and communication in 2012, contributing 4 or more articles per year with a medium–high citation impact. It is also worth noting that authors such as Casado-Aranda, Sánchez-Fernández or Bigné started contributing to the field in 2017, have published 3–4 papers per year and have already reached a considerable level of citations.

4.1.3 | Most relevant contributions employing neuromarketing tools in communication contexts

As it is expected that more recent publications will have a smaller number of citations, we identified the most impactful publications that applied neuromarketing methods in communication research. To that aim, we considered the average number of citations per year reached by each article, by dividing the general level global citations, GC, by the number of years since publication date. To reduce the bias that the inclusion of recent articles would introduce (as new articles may collect citations early on, but such a citation impact might not last), we limited the focus on papers with at least 5 years of citation impact. The local citations, LC, refer to the total number of citations that each article has received within the 861 studies under analysis. The LC/GC ratio, therefore, is an indicator of the impact of the article in our discipline of interest; a high ratio implies that it is a widely considered contribution in research applying neuromarketing tools in communication environments, and a low ratio indicates that it has had an impact on publications other than those selected, possibly in different fields of research. It can be observed (see Table 2) that most of the articles that receive the highest number of citations per year belong to the field of business, and mainly concerns work that applies eye-tracking methodology. The paper by Venkatraman et al. (2015) stands out in citation impact. This seminal study provided the first comprehensive comparison of neuroimaging tools (i.e., EEG and fMRI), psychophysiological measures (i.e., eye-tracking, skin

conductance, and heart rate) and regular self-report measures of ad persuasion, to predict market-level advertising effectiveness.

Furthermore, as shown in Table 2 only around 6%–23% of the citations received by the highest-impact articles come from publications in the same neuromarketing and communication discipline, thus revealing that, perhaps given their interdisciplinary nature and application, they may have had an impact (i.e., citations) on fields other than neuromarketing and communication.

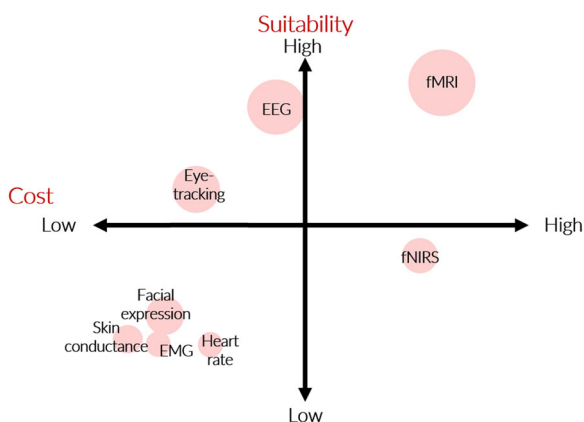
4.1.4 | Relative importance of neuromarketing tools in communication research

We manually coded the main neuropsychological tools used in each of the 861 contributions derived from the WoS search. The results indicate that fMRI (36% of contributions), EEG (25.7%), and eye-tracking (16%) were the most frequent tools within all the manuscripts. In turn, automated facial expression (6.5%), fNIRS (5.6%), heart rate (4.2%), skin conductance (3.7%), and EMG (2.3%) played a secondary/complementary role. Figure 5 depicts the different neurophysiological tools by cost and suitability in communication research (following Dimoka et al., 2012; Harris et al., 2018). Here, we define suitability as the ability of the neuromarketing tool to monitor comprehensive versus focused cognitive and affective reactions to communication stimuli which may serve as an accurate proxy or predictor of persuasion. Cost is defined here as the expenses for design, materials, instrumentation, and software necessary to obtain interpretable data from each experimental subject. The size of the circles refers to the number of studies conducted in marketing communications.

The neuroimaging tools of fMRI and EEG consolidate as two of the most commonly used tools in communication research. They constitute, indeed, noninvasive neuroimaging methodologies with high spatial and temporal resolution, respectively, that measure electrical and neural activity directly during the exposure of

TABLE 2 Highly cited publications in communication applying neuromarketing tools.

Publication	Average citations per year	Ratio local citations/global citations (%)
Venkatraman, V., Dimoka, A., Pavlou, P. A., Vo, K., Hampton, W., Bollinger, B., Hershfield, H. E., Ishihara, M., and Winer, R. S. (2015). Predicting advertising success beyond traditional measures: New Insights from neurophysiological methods and market response modeling. <i>Journal of Marketing Research</i> , 52(4), 436-452.	30.62	23.27
Pieters, R., and Wedel, M. (2004). Attention capture and transfer in advertising: Brand, pictorial, and text-size effects. <i>Journal of Marketing</i> , 68(2), 36-50.	26.21	13.86
Pieters, R., Wedel, M., & Batra, R. (2010). The stopping power of advertising: Measures and effects of visual complexity. <i>Journal of Marketing</i> , 74(5), 48-60. 10.1509/jmkg.74.5.048	20.92	8.82
Falk, E. B., Berkman, E. T., and Lieberman, M. D. (2012). From neural responses to population behavior: Neural focus group predicts population-level media effects. <i>Psychological Science</i> , 23(5), 439-445.	16.27	17.88
Falk, E. B., O'Donnell, M. B., Cascio, C. N., Tinney, F., Kang, Y., Lieberman, M. D., Taylor, S. E., An, L., Resnicow, K., & Strecher, V. J. (2015). Self-affirmation alters the brain's response to health messages and subsequent behavior change. <i>Proceedings of the National Academy of Sciences</i> , 112(7), 1977-1982. 10.1073/pnas.1500247112	15.12	12.40
Li, Q., Huang, Z. (Joy), & Christianson, K. (2016). Visual attention toward tourism photographs with text: An eye-tracking study. <i>Tourism Management</i> , 54, 243-258. 10.1016/j.tourman.2015.11.017	13.85	16.49
Piqueras-Fiszman, B., Velasco, C., Salgado-Montejo, A., & Spence, C. (2013). Using combined eye tracking and word association to assess novel packaging solutions: A case study involving jam jars. <i>Food Quality and Preference</i> , 28(1), 328-338. 10.1016/j.foodqual.2012.10.006	13.10	4.58
Boerman, S. C., van Reijmersdal, E. A., & Neijens, P. C. (2015). Using eye tracking to understand the effects of brand placement disclosure types in television programs. <i>Journal of Advertising</i> , 44(3), 196-207. 10.1080/00913367.2014.967423	12	16.67
Bang, H., & Wojdyski, B. W. (2016). Tracking users' visual attention and responses to personalized advertising based on task cognitive demand. <i>Computers in Human Behavior</i> , 55, 867-876. 10.1016/j.chb.2015.10.025	11.14	11.54
Bolls, P. D., Lang, A., & Potter, R. F. (2001). The effects of message valence and listener arousal on attention, memory, and facial muscular responses to radio advertisements. <i>Communication Research</i> , 28(5), 627-651. 10.1177/009365001028005003	9.5	9.57

**FIGURE 5** Most relevant neurophysiological tools by cost and suitability in communication research.

communicative elements (see Supporting Information: Material 1). Both methods stand out in providing a *comprehensive* insight into the brain processes underlying the processing of communication. Despite its relatively high cost, limited accessibility and strict restriction for motion, fMRI allows a whole brain measurement (lateral surface and depth) while static and dynamic stimuli are presented. The involvement of such deep emotional, memory, mentalizing, and valuation networks in communication contexts may be highly predictive of behavioral tendencies, persuasion, and conversion. Despite EEG being relatively more affordable and easier to implement, it does not allow a direct measure of deep brain structures where for example reward responses originate. However, its high temporal resolution enables moment-to-moment insight into the processing of a dynamic stimulus in terms of, for example, attention, memory activation, and approach-avoidance response. The granular scene by scene

information may help in detecting the strong and weak parts of the stimulus, enabling optimization. Recently, wireless EEG systems open up possibilities for mobile, in-store, and virtual reality studies.

Eye-tracking constitutes the most frequent psychophysiological tool in communication research as it reveals patterns of visual searching behavior while exposed to visual stimuli, including static (not dynamic) ads in websites, or communicational elements within the store shelf. This chance to capture, in a relatively inexpensive way, visual attention (not affective reactions though) is becoming even more relevant today given the recent growth of communications in social media and virtual environments. Eye-tracking, however, cannot directly inform about why someone is looking at something or the persuasion itself. For that reason, it is now often being complemented with neuroimaging tools such as EEG or other psychophysiological tools such as skin conductance, heart variability, electromyography, or automated facial reader. The latter psychophysiological methods inform specifically on some components of the general cognitive and affective reactions (e.g., skin conductance only measuring arousal) such that the general suitability for communication research of these methods is limited.

Another recently developed neuroimaging tool, fNIRS (see Supporting Information: Material 1), has become a relatively inexpensive, portable neuroimaging method that is less sensitive to motion artifacts. It measures frontal regions and surface analysis (not deep structures due to equipment constraints). This opens the door to be used in mobile and virtual reality communication environments. However, it suffers from interpretation challenges related to multiple sources of vascular signal and physiological noise related to superficial scalp signals, as well as low classification accuracies. Dieffenbach et al. (2021), indeed, made a call for communication researchers to use advanced fNIRS equipment and analysis techniques in more naturalistic contexts, as well as the consideration of measuring fNIRS signal in brain areas such as the inferior parietal lobule and inferior parietal and temporoparietal junction.

4.2 | Conceptual structure: Thematic analysis

The conceptual structure encloses the major themes that embody the corpus of knowledge in a scientific discipline. To unpack the conceptual structure of our area of interest, a science map of contributions making use of neuromarketing methods in communication research was made using two bibliometric analysis tools, namely, a wordcloud and a co-word analysis. A wordcloud is a visual representation of word frequency. The more commonly the term appears within the text being analyzed, the larger the word appears in the image generated (Atenstaedt, 2012). Some bibliometric analysis tools, such as Bibliometrix, can visualize the evolution of the frequency of topics over time (Aria & Cuccurullo, 2017). In turn, a co-word analysis develops clusters of publications based on the cooccurrence of keywords, wherein each cluster reflects a coherent theme (Chandra et al., 2022). This latter method allows us to clarify the importance and impact (i.e., development and influence) of the

topics in the field, thus revealing the most promising research gaps to address in communication research with neuromarketing tools.

4.2.1 | Frequency and evolution of themes: Wordcloud

As recommended by Aria & Cuccurullo (2017), before implementing the wordcloud, we removed the keywords used in the initial search in the WoS from the analysis. That is, we deleted all terms related to neuromarketing and its tools, as well as communication, advertising, and persuasion. This prevents the search terms from affecting the determination of the conceptual structure most commonly used in this line of research. Figure 6 illustrates the most frequent terms based on the occurrence of keywords used by the authors in the publications after filtering the data.

It can be observed that visual attention and emotion constitute the two mental processes that have attracted the greatest interest of studies using neuromarketing tools in communication contexts, even over others such as memory, engagement, recall, or perception. Evaluating consumer persuasion and behavior in the contexts of online advertising, health communication (smoking and alcohol), and social media with neuromarketing tools represents another of the most frequent lines of research. Although of less importance, the wordcloud also highlights the interest shown in evaluating persuasion within several media elements, including message framing, congruency, social influence, animated banner ads, celebrity endorsement, language, and music. Furthermore, it is worth noting the interest shown by neuromarketing studies in assessing message persuasion using deep learning and machine learning methods.

The Biblioshiny software was then used to capture a thematic evolution map summarizing the tendencies in the above-mentioned frequent topics. The period of interest was divided into three time zones based on the main stages of growth in scientific production in neuromarketing and communication research (as displayed in Figure 1): 1979–2007, 2008–2016, and 2017 to present. Each of the nodes represents a cluster, the height of each block reflects the



FIGURE 6 Wordcloud based on the authors' keywords that applied neuromarketing tools in communication research.

frequency of the research stream and the edges are their temporal evolution track generated by keyword cooccurrence of the topics between two time slices. Altogether, an alluvial diagram shows the structural changes that have occurred in the research field over time. Each subperiod occupies a column in the figure and is horizontally connected to preceding and succeeding significant clusters by stream fields. As explained by Li, Lu, and Xu (2022, p. 64839), the changes of the cluster structure from one subperiod to the next subperiod is represented by the mergers and divergences that occur in the ribbons linking the blocks at different subperiods during 1979–2023. In our case, we applied a minimum cluster frequency (per thousand documents) of 5, with the inclusion index as a weight proxy, and the Walktrap clustering algorithm (Cobo et al., 2011).

1979–2007: We name this period as *Foundations of neuro-physiological research and pioneering applications to marketing communications*. This period is characterized by salient use of eye tracking. In the 2000s, the majority of communication research focused on identifying the factors influencing visual attention, that is, the process by which one item is selected for analysis from among several competing items (APA, 2023). In particular, during this time frame, eye-tracking was applied to understand the bottom-up or top-down mechanisms through which certain ads or participants' characteristics, respectively, visually pop out of a visual scene and achieve greater attention than the competition. When it comes to bottom-up processes, in mass media communication, research has revealed that pictures versus logos/text (Pieters & Wedel, 2004, 2007), high- versus low-size images (Lohse, 1997), and original versus indistinct cues (Pieters et al., 2002) constitute the most effective media elements in visual attention, both in terms of pupil diameter and average fixation duration. Similar effects have been identified in digital (Bigne et al., 2021) and social media communications (Simonetti & Bigne, 2022).

However, additional eye-tracking studies have concluded that personal relevance Rosbergen et al. (1997), motivation (Pieters et al., 1999), consumer goals (Rayner, et al., 2001), and (brand) familiarity (Wedel & Pieters, 2000) elicit greater individual top-down control to select relevant information and deliberately direct attention to the specific locations of a stimulus. Apart from eye-tracking, this first period witnessed the pioneering neuroimaging studies that made use of EEG to unveil, for example, that longer alpha-blocking and occipital alpha are related to later-recognized, learned and salient advertisements (Rothschild & Hyun, 1990). Along the same line, the study by Rossiter et al. (2001) found that video scenes that elicited the fastest brain activity in the left frontal hemisphere were also better recognized, thus clearing up the neural patterns in executive processes and episodic memory encoding.

2008–2016: named as *Expansion of neurophysiological research: from physiology to neuroimaging applications*, during this period, neuroimaging research flourished. In this period, communication scholars started to realize the full potential of neuromarketing tools in communication research. In particular, there was an exponential boom in research employing both psychophysiological and neuroimaging methods aimed at exploring the cognitive and affective

reactions associated with message persuasion. Message persuasion refers to active attempts by an individual or social entity to change a person's beliefs, attitudes, or behaviors by conveying information, feelings, or reasoning. More specifically, the alluvial diagram shows the increasing interest in evaluating ad persuasion in online environments. For example, Sajjacholapunt and Ball (2014) found that the inclusion of faces with a gaze directed at the banner content (vs. at the viewer) captured more average fixation duration. Along the same line, Hernández-Méndez and Muñoz-Leiva (2015) concluded that tourists take longer periods and higher prior fixations to notice text versus images and static versus dynamic banners. Similarly, Boerman et al. (2015) made use of eye-tracking to understand the attentional effects of TV brand placement disclosure types. The visual attention toward the congruency between online ads and the webpage context was also analyzed by Hervet et al. (2011). A step forward from online environments is virtual environments. Scarce but promising efforts on virtual reality settings with neurophysiological tools emerged with the seminal paper of Bigné et al. (2016), who evaluated eye movements and brand choice in virtual supermarkets. Further research in this virtual reality context has been developed by Meißner et al. (2019).

Although attention processes continued to generate enormous interest in this period (mainly monitored through EEG and eye-tracking), a significant amount of scientific work emerged employing physiological tools such as skin conductance, EMG, or facial expressions, to measure emotion-related mechanisms, namely, arousal or valence reactions in communication contexts. For example, skin conductance research has compared the psychological arousal elicited by video versus high-imagery ads (Kim et al., 2014), radio versus TV ads (Peacock et al., 2011), and high versus low levels of commercial loading in online banners (Bellman et al., 2012). Similarly, EMG has been used to study the valence experienced when people are exposed to gain versus loss end-state environmental messages (Martínez-Fiestas et al., 2015), esthetic background images that vary in the emotional valence (Kätsyri et al., 2012) and pictures of alcoholic versus nonalcoholic beverages (Lang & Yegyan, 2014). Many scholars also used facial expressions in communication contexts. For example, Lewinski (2015) found that micro-facial patterns in response to YouTube videos predicted video's popularity over time. Further studies have similarly analyzed emotion-induced engagement through automated facial expressions in internet ads (Teixeira et al., 2012) or predicted ad liking and purchase intent based on facial expressions (McDuff et al., 2015).

Importantly, this period was characterized by the first use of fMRI to detect consumer brain activation during exposure to different types of ads and environments. For example, it was revealed the neural correlates (generally of adolescents) of emotions in TV commercials (Shen & Morris, 2016) and the brain processes underlying effects of high-expertise communicators and celebrities on memory and attitude (Klucharev et al., 2008; Stallen et al., 2010). Additional studies also explored the neural mechanisms elicited by logos (Bruce et al., 2014), vocal sounds in advertising (Mostafa, 2012), and messages promoting healthy behaviors, such as avoiding smoking

or stimulating exercising (Chua et al., 2009). Furthermore, groundbreaking neuroimaging studies, such as those by Falk (2012, 2016), Venkatraman et al. (2015), and Boksem and Smidts (2015), have made use of neural responses measured by EEG or fMRI during message exposure to predict out-of-sample population behavior beyond participant self-reports. The last years of this period also witnessed the development of functional connectivity analyses, which refer to evaluating the temporal coincidence of spatially distant neurophysiological events. It assesses the relationship between the measures of activity recorded for two brain regions while being exposed to messages. Scholars identified that coactivation of brain regions responsible for arousal, self-reference, value, and executive control predict subsequent self-reported ad liking and persuasion to TV commercials (Kühn & Gallinat, 2014; Melchers et al., 2015; Ramsay et al., 2013).

2017 to Present: We label this period as *Integration and synchronized neurophysiological tools*, characterized by the use of multiple tools. In the last lustrum, communication scholars also shifted the focus to more thoroughly measuring emotion (apart from attention) through neuromarketing tools. There was unprecedented growth in neuromarketing research evaluating persuasion in animated ads in online contexts and social networks (such as Facebook). In this regard, Mancini et al. (2022) and Greussing et al. (2020) evaluated attention in in-game sports and animated-interactive online ads, respectively. Along the same line, Bigné et al. (2023) combined eye-tracking and face-reader to evaluate how visual attention moderates negative emotions on brand trust and intention to share cause-related posts. Pozharliev et al. (2022) and Boerman and Müller (2022) made use of eye-tracking and EEG to study Instagram users' responses to influencer advertising. Similarly, Londoño and Ruiz de Maya (2022) assessed how anthropomorphizing retail cues influence consumer behavior and the moderating effect of the vice-virtue character of the displayed products. Along this line, Motoki et al. (2020) analyzed whether brain data can be used to forecast the viral marketing success of video ads on Facebook. Guixeres et al. (2017) assessed whether the effectiveness of a new ad on YouTube could be forecasted by using brain responses, heart rate variability, and eye-tracking. Furthermore, Laaksonen et al. (2019) employed EEG and EMG to further investigate how media brand knowledge influences emotional responses to news messages on Facebook. By means of EEG, eye-tracking, skin conductance, and facial coding, Ausin-Azofra et al. (2021) explored the effectiveness of 360-Degree versus 2D Video Ads. Using fMRI, Couwenberg et al. (2017) analyzed the difference in neural responses to experiential and functional ad appeals driving subsequent click-through rates. Similarly, Casado-Aranda (2022) recently analyzed neural responses to hedonic and utilitarian banners and associated them with subsequent participants' click-through-rate outcomes.

In this period also a novel metric emerged, namely neural synchronization, which was shown to be predictive of communication effects in the market level. Such neural synchronization (also called inter-subject phase synchronization or neural similarity) constitutes

an approach for exploratory analysis of task-fMRI data that reveals brain networks dynamically synchronized to task-features across participants (Xu et al., 2020). Neural synchronization is thought to assess a viewer's engagement with a message. Dmochowski et al. (2014) wrote a seminal paper using this method and found that neural synchronization elicited by SuperBowl ads was related to subsequent social media reactions and audience ratings. Along the same line, Barnett and Cerf (2017) used neural similarity (cross-brain correlation in the EEG alpha wave band) to predict movie trailer effects on memory and population-level ticket sales (Barnett & Cerf, 2017). More recently, in an fMRI study, Chan et al. (2019) found neural similarity during video watching to be predictive of out of sample ad recall and ad liking.

These 5 years also witnessed the emergence of neuromarketing studies evaluating persuasion in health and environmental communication contexts. Falk's research team, for instance, has consistently reported that the activation of the brain's valuation and self-relevance network during antismoking messages precedes later smoking reduction (Cooper et al., 2018; Kranzler et al., 2019). Similarly, Casado-Aranda, van der Laan, et al. (2022) concluded that neural activity in self-related brain regions in response to tailored nutritional messages predicts dietary changes. Another research line attempted to ascertain brain mechanisms elicited by different message frames in sustainable communications, namely, future versus past (Casado-Aranda, Martínez-Fiestas et al., 2018), congruent versus incongruent product-voice combinations (Casado-Aranda, Van der Laan et al., 2018), why versus how-focused messages (Vezich, Gunter, & Lieberman, 2017), environmental versus non-environmental messages (Vezich, Katzman, et al., 2017), and sustainable versus geographical versus healthy indications (Savelli et al., 2022). This period also included the first studies using fNIRS to monitor activity in the prefrontal cortices while the audience was exposed to persuasive sunscreen ads (Burns et al., 2018), health-related messages (Cuesta et al., 2020), and COVID-19 versus non-COVID-19 ads (Balconi et al., 2022). Unlike the prior period, most of these studies share an interest in identifying the ability of neural and psychological activity derived from persuasive messages to predict changes in user behavior beyond self-reported attitudes and intentions (Baldo et al., 2022).

One of the most promising lines of research in neuroimaging appears to be multi-voxel pattern analysis (MVPA). Instead of the conventional mass-univariate analysis, MVPA uses associations between voxels (activation patterns) and allows for differential responses across individual voxels, thus facilitating higher sensitivity. Current insights in affective neuroscience conceptualize emotions as distributed patterns of activations in a network of brain areas across the entire brain. MVPA methods are therefore best suited to properly assess (discrete) emotions (Kragel & LaBar, 2016). The incorporation of classifiers and machine learning in MVPA also constitutes one of the most prolific research lines in forecasting consumer behavior after message exposure (Chan et al., 2020; Shah et al., 2022) (Figure 7).

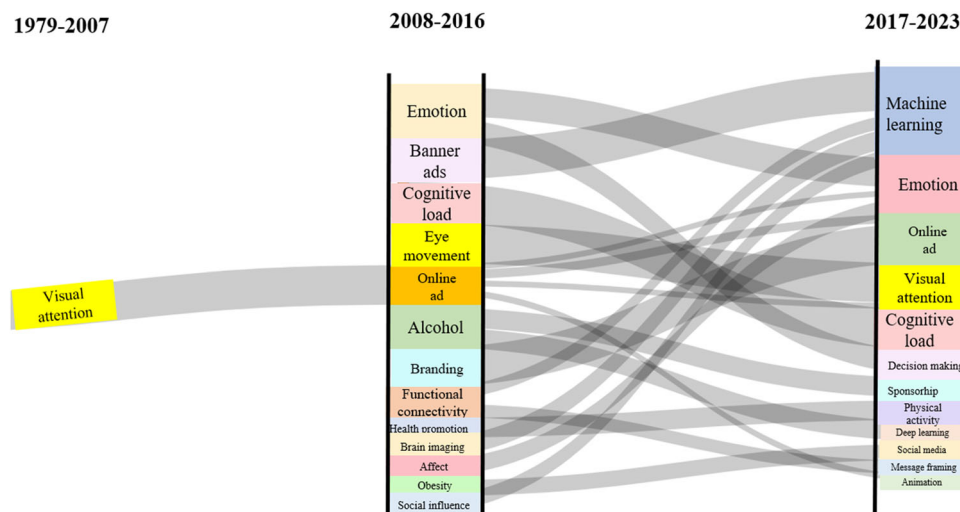


FIGURE 7 Alluvial diagram of the evolution of topics studied in communication research by means of neuromarketing methods.

4.2.2 | Theoretical approaches

To ascertain the diverse theoretical approaches that mostly contributed to the research applying neuromarketing methods in communication research, we followed the methodology of Mariani et al. (2022). Particularly, we searched for the keywords “theory” and “model” within the abstracts of the selected contributions. As a result, we found that 172 (out of 861) articles referred to a model or theory in the abstract. In particular, 65 different theories and models were identified. Table 3 summarizes the most commonly used theories sorted by the frequency of mentions.

Building upon models borrowed from psychology and neuroscience, the application of neuroimaging in the field of communication can constitute a novel source of understanding of the mechanisms underlying audience psychology and persuasion. For example, Falk and colleagues have recently made use of neuroimaging methods to provide a neuroscientific foundation of ELM and Theory of Mind models. Their results highlight the key role of brain regions involved with self-relevance, assessing the value of stimuli (i.e., subjective valuation), and understanding others' mental states (i.e., mentalizing) in successful and persuasive communication and recommendation propagation. They further show that mentalizing may be particularly key in processing negative recommendations (e.g., Baek et al., 2021). The neuroimaging findings of the study by Scholz et al. (2023) disambiguate a theoretical discussion in communication science (specifically, within the construal-level theory of psychological distance) and clarify the neuropsychological mechanisms that drive sharing decisions with few, well-defined others (narrow-casting) from sharing with loosely defined crowds (broadcasting). In particular, their results show the involvement of brain regions associated with both self-related and social processing in narrow and broadcasting, despite such processes were more intense during narrowcasting.

Providing solid support to these mentioned outcomes and to the postulates of the ELM, Casado-Aranda et al. (2023) have recently

shown that the involvement of self-related brain networks during eating recommendations are crucial for predicting nutritional behavior changes within a sample of unhealthy consumers. The authors even proved that the three mechanisms involved with ad memory formation, namely encoding, retrieval and recall, involve diverse brain systems, thus corroborating the axioms of the LC4MP (Casado-Aranda & Sanchez-Fernandez, 2022).

Further, based on Prospect Theory and Theory of Mind, Dimoka (2010) made use of fMRI in a website communication context to demonstrate that trust and distrust activate different brain areas and have different effects, helping explain why trust and distrust (and their dimensions) are distinct constructs associated with different neurological processes.

Apart from these theoretical approaches common in the general communication field, the analysis shows (although to a lesser extent) that there are specific neuroscience and psychology based theoretical accounts for studying communication. For example, the Cognitive Load Theory, which describes the limitations of the working memory to process incoming information, was used by Bigne et al. (2021) to show that cognitive load of consumers viewing user-generated content about a restaurant in TripAdvisor did not increase when an online ad is embedded in the page. Building upon such theoretical model, Kopacz et al. (2022) concluded that enriching instructional material with 3D visual effects does increase the number of fixations, as well as shortens fixation duration (i.e., increases attentional patterns).

Building upon Theory of Mind, some neuromarketing studies have made use of Social Identity Theories to reveal that the ability to understand the mental state of oneself and others while processing persuasive messages can have a crucial role in predicting individual behavior (Motoki et al., 2020; Read et al., 2019). Additional studies, furthermore, have reverted to attention-based theories, such as Scanpath Theory, Attention Restoration Theory, or the Dynamic Attention Theory, to understand attention wear-out and the impact of repetition on ad effectiveness by using eye-tracking devices (Hartmann et al., 2013; Pieters et al., 1999; Wooley et al., 2022).

TABLE 3 Most influential theoretical approaches in studies applying neuromarketing methods in communication research.

Theory	Main rationale	Sample articles
Elaboration likelihood model (ELM)	The basic tenet of the ELM is the presence of two routes to persuasion, central, and peripheral. Personally relevant and motivational messages can lead to a central processing route, which leads to a thorough consideration of the message by the person, thus making behavioral changes more likely. In turn, when the cognitive effort expended to process a message is low, the person processes the message through heuristic mechanisms, which leads to them relying on peripheral cues such as source credibility. These latter attitudes are not as predictive of subsequent behavior as those formed using the central route. In the field of neuromarketing, fMRI research has found that brain areas involved with self-relevance and value during message exposure are crucial to predict behavior.	Giraldo-Romero et al. (2021); Vezich, Gunter, and Lieberman (2017); Wang et al. (2019); Barbier et al. (2020); Falk et al. (2011); Casado-Aranda, Sánchez-Fernández, et al. (2022)
Limited capacity model of motivated mediated message processing (LC4MP)	According to LC4MP, processing messages requires three pivotal subprocesses: encoding, storage, and retrieval. Encoding refers to the process of selecting relevant information and aspects from the message for further processing, while storage involves linking recently encoded information to previously stored information. Only messages and/or content that are motivationally relevant and novel elicit greater resource allocation, leading to higher message encoding and storage processes, thus facilitating greater recognition and recall.	Gong and Chu (2022); Xu (2017); Casado-Aranda and Sanchez-Fernandez (2022); Leshner et al. (2021); Patel et al. (2014)
Dual process theory	This consists of a decision-making theory stating that judgment and reasoning involve two separate processes: intuitive, implicit, and automatic decision-making and rational, explicit, and controlled decision-making. Neuromarketing studies attempt to clear up the physiological and neural mechanisms underlying both systems (e.g., during utilitarian vs. hedonic message frames).	Zhang and Lee (2022); Pozharliev et al. (2022); Yang et al. (2022); Bigne et al. (2021); Bodie (2012)
Theory of mind	This refers to the cognitive process of considering the mental states of others. This mechanism is likely to be experienced in both communicators deciding to share and receivers being influenced.	Motoki et al. (2020); Bašnáková et al. (2014); Falk and Scholz (2018); Baek et al. (2017); Falk et al. (2013)
Stimulus organism response theory (S-O-R)	In communication research, SOR implies that some media elements act as a stimulus (S) that influences a receiver's internal state (O), which subsequently derives the individual's behavioral response or behavior (R). Neuromarketing investigations have analyzed the extent to which the message frames elicit neural or physiological mechanisms involved with persuasion, which could further forecast behavior.	Yang et al. (2022); Fei et al. (2021); Kakaria et al. (2023); Bigne, Chatzipanagiotou, and Ruiz (2020)
Psychological reactance theory	This theoretical approach holds that any persuasive message can arouse a motivation (called reactance) to reject the desired behavior. One of its basic claims is that messages that exert a lot of pressure on the audience are likely to be seen as threats to freedom. The theory postulates that when a freedom is threatened, the individual will be motivated to restore that freedom by increasing their preference for the threatened option (e.g., unhealthy eating or smoking), abrogating or denying the source of the threat or	Clayton (2022); Clayton et al. (2019); Wang et al. (2019); Añaños-Carrasco (2015)

(Continues)

TABLE 3 (Continued)

Theory	Main rationale	Sample articles
	exercising a different freedom. For example, neuromarketing studies analyze neural and psychological reactions to assertive versus nonassertive messages.	
Regulatory focus theory	This theory considers two types of self-regulatory guidelines that encourage audiences to obtain a desired end-state: focusing on obtaining pleasure and/or avoiding pain or loss. These approaches are described with the concepts of "promotion" and "preventive." Most neuromarketing research has used this theoretical model in assessing persuasion in communication campaigns boosting sustainable and healthy lifestyles.	Giraldo-Romero et al. (2021); Li, Liu, and Xie (2022); Casado-Aranda et al. (2017); Vezich, Katzman, et al. (2017)

In sum, while we find that most studies still take existing psychological theories as their core frame of reference, a further growth in cognitive neuroscience may provide more avenues to generate biologically plausible theoretical accounts of communication processing and effects.

4.2.3 | Content analysis through keyword cooccurrence: Revealing future research avenues

Finally, we aimed to pinpoint the conceptual structure of the communication discipline using a content analysis based on the cooccurrences of words in the 861 contributions we analyzed. A co-word analysis consists of a content analysis tool that uses patterns of cooccurrence in several elements within a collection of manuscripts with the aim of recognizing the links between ideas within the topics included in the corpus of texts. In our case, the word cooccurrence phase used text-mining tools for *authors' keywords*, which led to the development of a strategic diagram highlighting the relative relevance of the topics discussed in the neuromarketing and communication discipline over the last three decades. This strategic diagram represents a graph, as implemented with the Bibliometrix software, that highlights the main topics according to their density and centrality. According to Cobo et al. (2011, p. 150):

- Centrality measures the degree of interaction of a network with other networks (Callon et al., 1991). Therefore, centrality measures the strength of external ties to other themes. We can interpret this value as a measure of the importance of a theme in the development of the entire research field analyzed.
- Density, in turn, is related to the internal strength of the network (Callon et al., 1991). Density measures the strength of internal ties among all keywords describing the research theme, thus is being understood as a measure of the theme's development.

The union of low and high intensities of density and centrality facilitates the establishment of four quadrants: driving themes (strong

centrality and high density), very isolated themes (low centrality and high density), emerging themes (low centrality and density), and core themes (high centrality and low density) (Cobo et al., 2011).

In our approach we used the main defaults detailed by Cobo et al. (2011). In particular, we first selected the keywords identified by the author. Then we used a minimum frequency of two words from a cooccurrence matrix to calculate the similarities between the selected items. We then used an equivalence index as a normalization measure. We also followed the Simple Center Algorithm, with a maximum network size of 4 and a minimum of 1. The objective of this phase was to clarify the most relevant networks. Finally, we used the "number of papers" and "number of citations" as measured the strategic diagram's quality.

The main diagram of the investigated themes shows that the *driving or motor themes*, are themes that are both well developed and with a high potential to form the basis of neuromarketing and communication research structures. These themes are: *animation*; *deep learning*; *virtual reality*; and, with a lesser degree of relevance and development (i.e., with higher potential), *social marketing*. These themes, in fact, correspond to the most frequent keywords in the last 5 years of research in the discipline. Consequently, prospective research is in a good position to explore communication phenomena using neuroimaging tools supported by learning methods in messages inserted into social (e.g., sustainable-, non-profit-, and health-related campaigns), online (animated and interactive), and virtual reality contexts. For example, further studies could solve the following questions: What are the levels of audience conflict, or even pleasant psychological states, elicited by audiovisual features embedded in the ad, such as medium-brand image congruency? What are the neural mechanisms involved in self-control experienced by online gamblers when they are exposed to messages advising more responsible gambling? How can brain/physiological reactions to messages encouraging environmental habits predict changes in a user's sustainable behavior?

The bottom-right quadrant, in turn, illustrates the *transversal themes (basic themes)*; although they constitute common topics of useful application to different contexts of study and communications

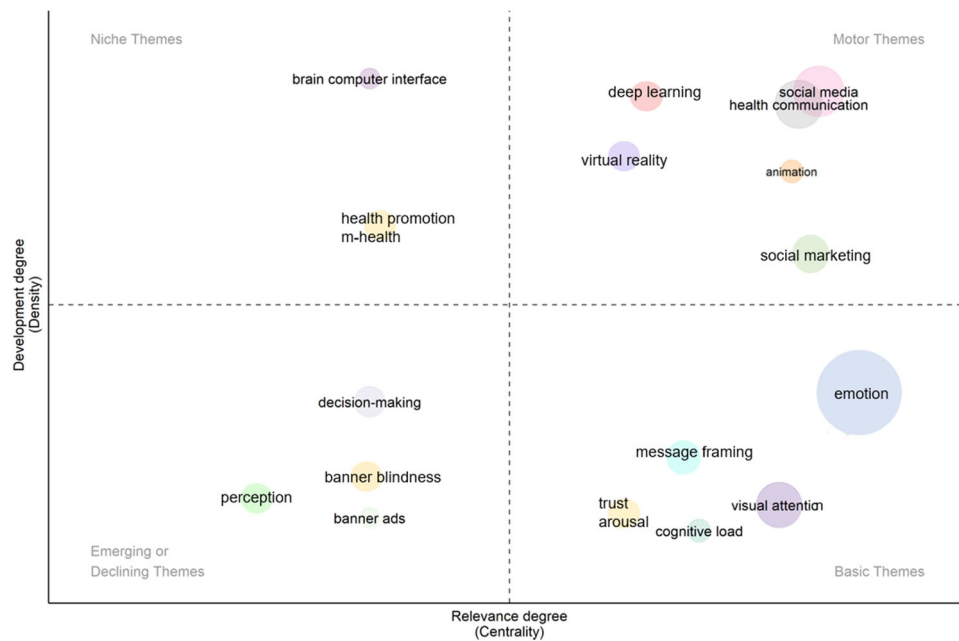


FIGURE 8 Strategic diagram of evolving theme in applying neuromarketing methods in communication research.

types, they may have less impact on future research as specific entities of study. In particular, the following should be considered as basic themes in future neuromarketing and communication studies: *visual attention*, *arousal*, *trust*, *cognitive load*, *message framing*, and *emotion*. Visual attention is still a pertinent theme which may grow in impact because online (webcam) eye-tracking becomes better, and neuromarketers are heavily investing in artificial intelligence models of predictive eye-tracking.

Health promotion and *brain-computer interface* constitute moderately developed topics. They currently have received relatively scarce attention but with a high potential to become mainstream (i.e., *niche themes*). For example, further investigations are required to identify the psychological determinants of persuasion in m-health environments.

The bottom-left quadrant refers to topics with currently scarce relevance. They could be declining or instead emerging and may start playing a decisive role in future research (*emerging themes*). Indeed, its value as pillars of neuromarketing in communications research will provide useful frameworks for extending research to new contexts or neural correlates. Specifically, *banner blindness*, *perception*, and *decision-making* stand out here. Consequently, it appears that the use of neuromarketing measures in assessing consumer engagement, perception, and decision-making processes could increase its relative importance in prospective neuromarketing studies (Figure 8).

5 | IMPLICATIONS AND RESEARCH DIRECTIONS

We additionally propose the following typology of prospective communication research applying neuromarketing methods. It can be broadly categorized into three different types of approaches,

namely research applying neuromarketing tools, research linking neurophysiological metrics to marketing relevant metrics and research on neurophysiological correlates.

5.1 | Communication research applying neuromarketing tools

The type of research applies direct metrics as obtained from neurophysiological tools to study phenomena and mechanisms in communication. It assumes that psychological constructs are reliably and validly measured by these neurophysiological tools, such as attentional time (e.g., eye-tracking), emotion (e.g., through facial expressions), heart variability (e.g., HRV), arousal (e.g., GSR), withdrawal behavior (e.g., EEG), cognitive workload (e.g., EEG), self-referential thinking (e.g., fMRI). Our study shows a clear trend in the application of these tools to understand the cognitive and affective processes underlying effective communication. Since these tools are becoming more mainstream and easily available, we foresee a further growth in the fruitful use of these methods in both academic and practical communication research.

5.2 | Communication research linking neurophysiological metrics to marketing relevant metrics

Since not all metrics obtained from neurophysiological measures are rooted in the communications literature, research is called for that focuses on determining the validity and added value of neurophysiological metrics by associating these metrics to marketing

relevant persuasion-related constructs, such as brand recall, attitudes, purchase intention, brand experience, or behavior. Therefore, researchers could make greater efforts in evaluating the relationships between neuropsychological measures and traditional self-reported or actual consumer behavior after message exposure.

5.3 | Basic research on neurophysiological correlates

The bundle of different tools, their cost, and the difficulty of implementing them for any study, calls for research on how metrics from different devices correlate. This implies a multi-method approach assessing convergent and discriminant validity. For instance, how do eye-tracking metrics correlate with brain activations to assess engagement? Venkatraman et al. (2015) provided a first insight into how different neurophysiological tools for predicting market-level advertising success mutually correlated. Guixeres et al. (2017) analyzed ad liking, ad recall, and predicted online views through EEG, HRV, and eye-tracking.

In addition to these three general types of neuromarketing research directions, it is worth highlighting the lack of education of students and marketing professionals in neuromarketing methods, as well as the added value of cognitive and affective neuroscience theories in communication research (Brenninkmeijer et al., 2020). We therefore advocate to set up courses and seminars at different educational levels in neuromarketing methods and cognitive and affective neuroscience insights, as well as develop and strengthen fruitful and international academic and professional networks in neuromarketing and communication research. The inclusion of marketing scholars with neuro background in journal' editorial and review boards as well as the launch of special issues dedicated to build theoretical and empirical corpus of knowledge in neuromarketing and communication research, could also greatly make a difference in this regard.

Overall, the three categories of future research and suggested initiatives provide a framework for guiding future research and practice in neuromarketing to improve our understanding of the neurophysiological responses of consumers to marketing communication stimuli.

6 | CONCLUSIONS

This study makes several key contributions to the literature on neuromarketing and communication. First, in the last 5 years, a multitude of bibliometric and systematic literature reviews have been conducted aiming to assess the evolution of scientific production, identifying main journals and prominent themes in the general field of neuromarketing and consumer neuroscience (Bhardwaj et al., 2023; Harris et al., 2018; and Zhu et al., 2022, among others). Here, we have made headway by implementing a focused and comprehensive review of the application of neuromarketing methods in

communication research. To the best of our knowledge, none of the above-mentioned bibliometric analyses either approached the authors' production over time, the development of frequent topics, or the theoretical models adopted to obtain a better understanding of neuromarketing and communication research. By incorporating these lenses, the current literature review draws a more compelling picture of the conceptual structure of the use of neuromarketing in communication research.

Second, our performance analysis shows continuous growth in scientific production regarding the application of neuromarketing methods in communication, mainly over the last decade. Nevertheless, the impact of these publications (in terms of citations) has slightly declined after reaching a peak in the 1999–2003 period (RQ1). The peak was mainly driven by some very impactful papers such as those by Pieters and Wedel (2004) and Bolls (2002). The analysis of the most influential sources highlights that studies applying neuromarketing tools in communication contexts appear in journals from interrelated disciplines, including business, communication, neuroscience, and psychology. In particular, the contributions published in business and communication journals (such as the *Journal of Marketing Research*, *Journal of Interactive Marketing*, or *Journal of Advertising*) have the greatest impact and, therefore, should be further considered by scholars interested in this research branch. Indeed, the contributions with the highest average citations per year have been published in such business outlets. The findings also highlight that eye-tracking and neuroimaging tools (mainly EEG and fMRI) constitute the most frequent methods employed in communication research (RQ2).

The findings furthermore indicate (RQ3) that the most frequently tested theories not only constitute traditional models of information processing and persuasion (such as the ELM or LC4MP) but also theories borrowed from social psychology and neuroscience (such as Theory of Mind, Mentalizing, Social Identity Theory, or Psychological Reactance Theory) and behavioral psychology (such as SOR). We propose that the main theoretical corpus that future scholars in neuromarketing and communication could focus on is the development of novel theoretical perspectives informed by increasing knowledge about underlying brain processes.

Answering RQ4, the current manuscript advances the conceptual structure of neuromarketing and communication literature by synthesizing, connecting, and identifying topical areas and thematic networks of great frequency, development and relevance. The wordcloud and alluvial diagram show the evolution of the most frequent themes investigated in the field. We differentiated three periods: (1) From 1979 to 2007, most literature used eye-tracking and EEG to explore the bottom-up or top-down mechanisms involved with attention; (2) The 8 years that followed that period (2008–2016) involved eye-tracking and EEG neuromarketing tools increasingly being used to assess ad persuasion in online and virtual contexts. Furthermore, the use of physiological tools such as skin conductance, electromyography, or automated face expressions to monitor emotional reactions to ads became widespread. Importantly, during this period, there was a dramatic increase in contributions using fMRI

to understand the neural processes involved in persuasion elicited by different message frames. In addition, an increasing number of studies predicted market-level behavior by using neural or physiological data during advertising exposure; (3) From 2017 onwards, neuromarketing research has focused on assessing emotional reactions to messages embedded in social networks, as well as in health and sustainable communications. The main interest of current neuromarketing studies lies in evaluating the extent to which audience behavioral changes can be predicted by using neuromarketing data, beyond self-reported measures. There is a growing interest, furthermore, in a novel metric, namely neural synchronization, and its ability to predict communication effects in the market level. Moreover, machine and deep learning are emerging as tools that could make a big difference in that regard.

Complementing the above-mentioned findings, this review also opens avenues for future studies in neuromarketing and communication research. Specifically, our content analysis using the cooccurrence of the authors' keywords depicted a strategic diagram mapping the driving, basic, niche, and declining topics based on the criteria of density and centrality. Particularly, the co-word analysis illustrates that the study of animated banners, ads in virtual environments and social marketing, as well as the complementary role of deep learning, constitute promising fundamental research streams in neuromarketing and communication research. The strategic diagram also revealed that the use of brain tools to unveil the neural mechanisms involved in emotions, trust, cognitive load, arousal, or attention should be taken as the basis of additional research on neuromarketing and communication. Finally, the evaluation

of ads within m-health and brain-computer interfaces are becoming mainstream and deserve further assessment in different communication contexts and marketing scenarios. Figure 9 now summarizes the main contributions of this paper.

As to the limitations of this study, it is worth noting that we opted to use the WoS over Scopus or Google Scholar as a database. Whereas Scopus or Google Scholar indexes may provide a wider corpus of literature, including the most recent conference proceedings (Mariani et al., 2022), using them increases the complexity of retrieving meaningful metadata for large-scale bibliometric studies. The WoS was also selected because it includes the sources with the greatest impact in the field of marketing and psychology (Martín-Martín et al., 2018). Furthermore, as Aria and Cuccurullo (2017) mentioned, the WoS is generally preferable for data quality (i.e., reference items are standardized, the availability of Keywords Plus or very few missing data) and provides more accurate inputs to work with the Bibliometrix software. Indeed, prior reviews have previously used the WoS as a database of interest (Bastidas-Manzano et al., 2021; Yuan et al., 2019). Prospective studies may also collect data from diverse databases. Despite these drawbacks, the current study is the first bibliometric analysis providing an overview of the evolution, current streams, and potential domains of interest for neuromarketing academics interested in communication research. Hence, the results offer communication scholars and experts an accurate framework of recent scientific research and insights that can shape further studies.

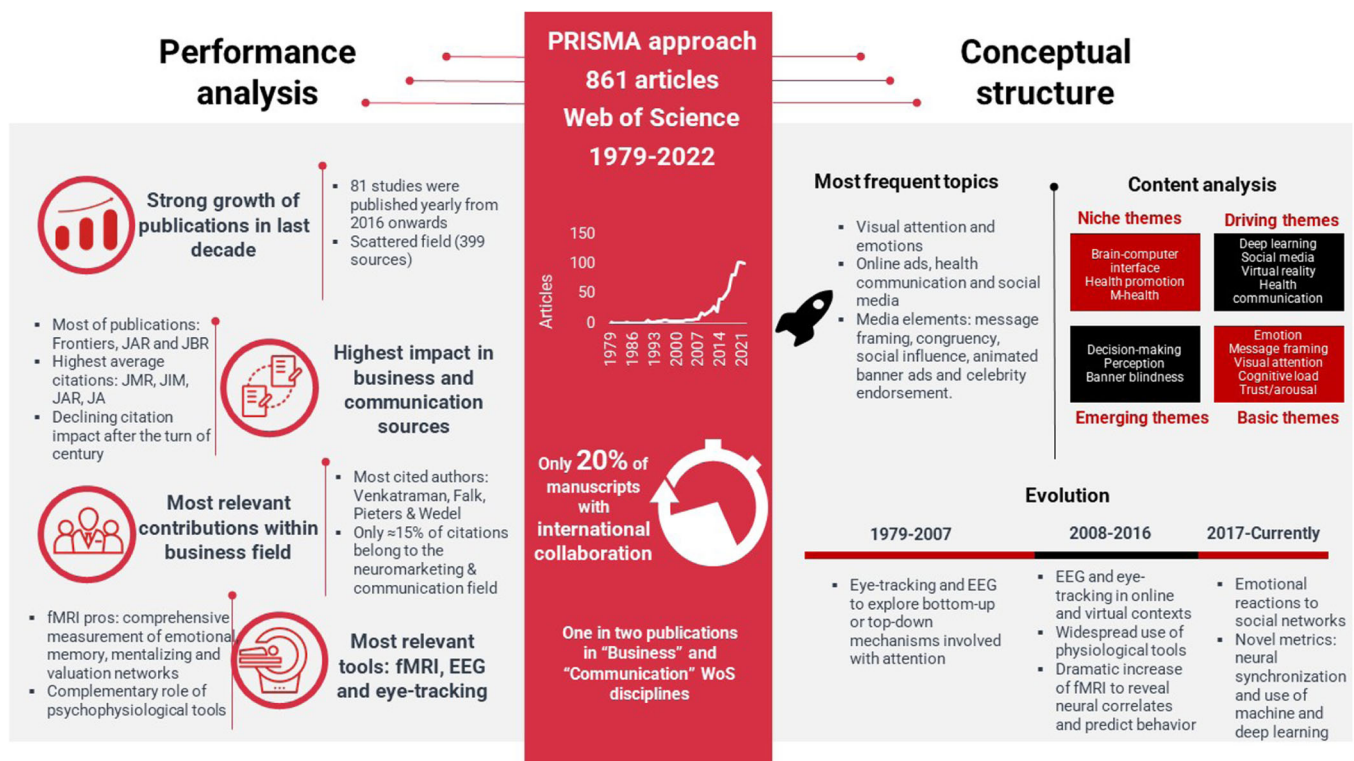


FIGURE 9 Main contributions of the current manuscript.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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