

REVIEW ARTICLE

Neuroethics in pharmaceutical neuromarketing: Applications and limitations

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Citation: Nehra B, Bishnoi M, Kumar M, *et al.* Neuroethics in pharmaceutical neuromarketing: Applications and limitations. *Adv Neurol*.
doi: 10.36922/AN026190017

Received: May 6, 2026

Revised: June 22, 2026

Accepted: July 13, 2026

Published online: July 31, 2026

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Abstract

Neuromarketing integrates neuroscience, psychology, and marketing to investigate the neural and emotional mechanisms underlying consumer decision-making and behavior. In the pharmaceutical industry, decision-making among patients and healthcare professionals is complex and emotionally influenced. Herein, neuromarketing provides a data-driven approach to assess communication and perception toward a brand. In this context, a semi-systematic review of the literature was conducted by compiling selected studies published between January 2005 and January 2026 in major scientific databases (PubMed, Scopus, Web of Science, Google Scholar). This review highlights the scope, applications, and ethical implications of neuromarketing within the pharmaceutical domain. Findings indicate that neuromarketing helps clarify the cognitive and emotional drivers that influence preferences for pharmaceutical products and brand loyalty. Among the various neuromarketing tools, functional magnetic resonance imaging and electroencephalography provide neural insights into emotional responses and attention to marketing cues. Meanwhile, eye-tracking and galvanic skin response quantify visual focus and physiological arousal. These data facilitate evidence-based optimization of marketing strategies. However, various ethical challenges persist, including data privacy, small sample sizes, methodological variability, informed consent, and the risks of psychological manipulation. Thus, integrating neuroscientific data into marketing requires standardized methodologies and robust regulatory frameworks to ensure transparency and consumer protection.

Keywords: Neuromarketing; Pharmaceutical; Functional magnetic resonance imaging; Electroencephalography; Eye-tracking

1. Introduction

Neuromarketing has become the cutting-edge approach to investigating consumer behavior by combining psychology, neuroscience, and sophisticated analytics. It offers a complex and empirically supported understanding of the factors that influence customer behavior. Neuromarketing examines the hidden emotional and cognitive mechanisms that affect decisions, rather than conventional marketing research techniques, which mostly rely on surveys and self-reported opinions that can be skewed or incomplete. It gives marketers unusual access to unconscious mechanisms influencing memory, attention, emotional resonance, and judgement.¹ Over the last two decades, neuromarketing has evolved from an academic curiosity into a useful toolkit used by international businesses across industries, such as retail, food, banking, and entertainment. Before delving deeper into the use of neuromarketing in the pharmaceutical business, this section methodically examines the scientific underpinnings and practical approaches in this field. In the early 2000s, neuroscientists and marketers began collaborating to address gaps in conventional market research techniques that had emerged in neuromarketing.^{2,3} Biases such as societal appeal, memory problems, and a lack of introspective insight into the genuine intentions of people limit the useful declarative data about consumer preferences (which focus groups, surveys, and interviews provide). To overcome these constraints, neuromarketing measures neurological and physiological responses indicative of unconscious processes.⁴ Neuromarketing has a wide range of uses, including retail spaces, product designs, and advertising campaigns. Key objectives of neuromarketing strategy include decoding consumer decision-making, improving market effectiveness, boosting customer engagement, optimizing product design or location, and reducing marketing waste.⁵

To create a comprehensive picture of consumer reactions, neuromarketing uses a broad range of scientific tools from behavioral science and cognitive neuroscience. One of the most effective methods is functional magnetic resonance imaging (fMRI), which analyzes changes in blood oxygenation to produce high-resolution images of brain activity. Brain areas linked to valuation (e.g., the ventromedial prefrontal cortex), emotional processing (e.g., the amygdala), reward (e.g., the ventral striatum), and memory storage (e.g., the hippocampus) have been investigated using fMRI.^{6,7} Nucleus accumbens activity has been shown to predict purchasing decisions and even market-level sales, providing marketers with predictive insights. In contrast, electroencephalography (EEG) offers better temporal resolution and can assess real-time

changes in brainwave activity while participants watch commercials or use products.⁸ EEG can detect indicators of emotional sensitivity (e.g., asymmetry in frontal cortical activity), cognitive strain (e.g., parietal alpha suppression), and attention (e.g., frontal theta power).⁹ Eye-tracking technology is incredibly useful for optimizing websites, advertising layouts, and packaging because it can precisely detect consumers' focus on visual elements. Consequently, design alterations can be informed by heat maps and gaze plots, which can reveal whether important messages are observed or disregarded.¹⁰

Meanwhile, heart rate variability (HRV) provides information on stress and engagement, while galvanic skin response (GSR) gauges changes in sweat gland function during emotional arousal.^{11,12} According to Ekman and Friesen¹³, facial coding systems analyze micro-expressions to classify emotional states, such as happiness, surprise, fear, and disgust. These methods are commonly combined in multimodal studies, enabling triangulation of findings and a more robust interpretation. For example, an advertisement can afford high attention (eye-tracking, EEG) but low emotional engagement (GSR, facial coding), indicating a need for increased affective resonance. Moreover, advanced neuromarketing studies typically incorporate behavioral outcomes (e.g., click-through rates, purchase data) to validate predictive scores of neural and biometric measures. [Table 1](#) summarizes the principal neuromarketing-related acronyms, their definitions, measured parameters, and commonly reported units.

2. Literature review

2.1. Evolution of neuromarketing research

Neuromarketing emerged in the early 2000s as an interdisciplinary field that integrates neuroscience, psychology, behavioral economics, and marketing sciences to better understand consumer decision-making.¹⁴ Traditional approaches of market research (e.g., surveys, interviews, and focus groups) generally rely on self-reported responses that can be affected by recall bias, social desirability bias, and limitations in conscious introspection.^{15,16} To overcome these challenges, neuromarketing introduced neurophysiological techniques that can directly measure subconscious cognitive and emotional responses.¹⁷ In the past two decades, advances in neuroimaging technologies, such as fMRI, EEG, eye-tracking, GSR, and facial coding, have enabled researchers to investigate the neural correlates of attention, emotional engagement, reward processing, trust formation, and purchase intentions. Hence, neuromarketing evolved from an experimental academic discipline into a practical decision-support tool, i.e., employed across multiple

Table 1. Nomenclature and description of major neuromarketing acronyms

Acronym	Full name	Definition	Values/Parameters assessed	Unit(s)
EEG	Electroencephalography	A neurophysiological technique that records electrical activity generated by cortical neurons through scalp electrodes.	Brain wave activity (alpha, beta, gamma, theta, delta bands), attention, engagement, emotional valence	μV (microvolts), Hz
fMRI	Functional magnetic resonance imaging	A neuroimaging technique that measures alterations in blood oxygenation associated with neural activity.	BOLD signal, regional brain activation, reward processing, decision-making	BOLD %, arbitrary signal units
MEG	Magnetoencephalography	Non-invasive method that records magnetic fields generated <i>via</i> neuronal electrical activity.	Brain activity localization and temporal dynamics	fT (femtotesla)
PET	Positron emission tomography	Functional imaging modality that measures metabolic activity utilizing radioactive tracers.	Glucose metabolism, regional brain activity	kBq/mL, SUV
ET	Eye tracking	Technique employed to monitor eye movements and visual attention toward stimuli.	Fixation duration, gaze path, dwell time, pupil response	ms, mm, pixels
GSR	Galvanic skin response	Measurement of changes in skin conductance caused by autonomic nervous system activation.	Emotional arousal, stress response	μS (microsiemens)
HRV	Heart rate variability	Variation in time intervals between consecutive heartbeats that reflects autonomic regulation.	Sympathetic and parasympathetic balance, stress, engagement	ms
ECG	Electrocardiography	Technique employed to record the electrical activity of the heart.	Heart rate, cardiac rhythm, emotional activation	bpm, mV
EMG	Electromyography	Technique used to measure electrical activity generated through skeletal muscles.	Facial muscle activation, emotional expression	μV
FACS	Facial action coding system	Standardized system for coding facial muscle movements associated with emotions.	Emotional expressions and facial responses	Categorical scores
BOLD	Blood oxygen level-dependent signal	fMRI-derived indicator that indicates oxygenation alteration associated with neuronal activity.	Regional brain activation intensity	Relative signal intensity
tDCS	Transcranial direct current stimulation	Non-invasive brain stimulation technique that utilizes low-intensity electrical current.	Cortical excitability modulation	mA
TMS	Transcranial magnetic stimulation	Brain stimulation technique with the help of magnetic pulses to modulate neural activity.	Cortical response and neural activation	Tesla (T)
AI	Artificial intelligence	Computational systems that can simulate human learning and decision-making processes.	Pattern recognition, predictive analytics	Not applicable
BCI	Brain-computer interface	It allows direct communication between neural signals and computing systems.	Brain signal decoding and user interaction	Signal-dependent
SSVEP	Steady-state visual evoked potential	EEG response generated by repetitive visual stimulation.	Attention and visual processing	μV, Hz
GDPR	General Data Protection Regulation	European regulatory framework that governs the collection and processing of personal data.	Data privacy compliance	Not applicable
HIPAA	Health Insurance Portability and Accountability Act	The United States legislation that protects healthcare-related personal information.	Data security and confidentiality	Not applicable

Abbreviation: SUV: Standardized uptake value.

industries.¹⁴⁻¹⁸

2.2. Applications of neuromarketing across different sectors

Neuromarketing is widely employed across diverse sectors to investigate consumer behavior based on cognitive and emotional responses.^{19,20} In the retail sector, techniques such as eye-tracking, GSR, and HRV have demonstrated that product placement, store layout, ambient factors, and sensory cues significantly influence consumer attention, navigation, and purchasing behavior, thereby optimizing the customer experience and sales outcomes.^{21,22} In the food and beverage industry, neuromarketing shows that branding and packaging can modulate sensory perception and emotional anticipation. This was evidenced by neuroimaging and biometric studies that examined elevated reward-related brain activity and consumer engagement to facilitate more effective product design and marketing strategies.²³ In financial services, decision-making is affected by heuristics and emotional biases. Neuromarketing tools, including EEG, fMRI, and eye-tracking, are used to assess trust, cognitive load, and the effectiveness of communication, thereby increasing user experience and transparency in tightly controlled situations.^{24,25} Meanwhile, neuromarketing helps the media and entertainment industry optimize content using EEG and facial coding techniques. These techniques enable real-time measurement of attention and emotional involvement. On the other hand, eye-tracking and neuroimaging aid in improving narrative structures, visual components, and user interfaces to improve audience retention and minimize cognitive overload.²⁶

Despite notable advancements in neuromarketing research, the published literature is primarily descriptive, with little attention paid to its implementation in the pharmaceutical industry. Moreover, the majority of research focuses on consumer behavior or the capabilities of technology, but neither addresses the role of neuromarketing in a more regulated pharmaceutical industry. Furthermore, inconsistencies in study design, small sample sizes, and lack of standardized methodologies limit the reproducibility of results. In addition, there is a lack of critical synthesis that addresses the balance between commercial objectives and patient welfare. Therefore, this review aims to provide a focused compilation of applications of neuromarketing in the pharmaceutical domain, assess methodological strengths and limitations, and highlight regulatory challenges.

2.3. Current status of neuromarketing in healthcare and pharmaceutical marketing

Compared with other sectors, adoption of neuromarketing in the healthcare and pharmaceutical industries remains relatively limited but is rapidly gaining attention. Pharmaceutical decision-making involves complex interactions among patients, healthcare professionals, caregivers, regulatory authorities, and industry stakeholders.^{27,28} Unlike traditional consumer products, pharmaceutical products are directly associated with health outcomes, treatment adherence, and patient safety. Therefore, it becomes very important to understand emotional and cognitive responses toward pharmaceutical advertisements, patient education materials, medication packaging, and healthcare communications. Neuromarketing techniques offer opportunities to investigate how patients process risk-benefit information, perceive treatment efficacy, develop trust in pharmaceutical brands, and respond to educational interventions designed to improve medication adherence. Furthermore, healthcare professionals can benefit from communication strategies (optimized through neuroscientific insights) that decrease cognitive load while retaining information.^{29,30}

2.4. Research gaps and importance of the present review

Despite growing interest in neuromarketing applications, available literature remains fragmented and predominantly focused on general consumer behavior. Many published studies emphasize the technological capabilities of neuromarketing tools without critically assessing their practical implications for healthcare communication and pharmaceutical marketing.^{16,27,29} Additionally, methodological heterogeneity, small sample sizes, lack of standardized protocols, and ethical concerns that surround privacy and potential manipulation continue to limit the translation of findings into routine pharmaceutical practice. In addition, limited literature is available that integrates neuroscientific methodologies, pharmaceutical applications, ethical considerations, regulatory challenges, and future research directions within a single framework. Therefore, the present review aims to address these gaps by carefully evaluating the applications, opportunities, limitations, and neuroethical implications of neuromarketing in the pharmaceutical sector.²⁷⁻³¹

3. Methodology and analysis

3.1. Review design

The present study was conducted as a semi-systematic review to examine applications, limitations, ethical implications, and future prospects of neuromarketing

within pharmaceutical and healthcare settings. A semi-systematic review approach was selected because the topic spans multiple disciplines, including neuroscience, marketing, psychology, healthcare communication, pharmaceutical sciences, and consumer behavior. Unlike conventional systematic reviews, a semi-systematic approach allows for the integration of conceptual, empirical, and methodological studies to provide a broader understanding of emerging and interdisciplinary research fields. This approach is considered suitable to assess the evolving role of neuromarketing technologies in pharmaceutical communication, patient engagement, physician interactions, and healthcare decision-making.

3.2. Literature search strategy

A comprehensive literature search was conducted to identify relevant studies that examine neuromarketing applications, neuroscientific methodologies, pharmaceutical marketing strategies, and healthcare communication practices. In this regard, electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, were systematically searched to retrieve peer-reviewed articles published from January 2005 to January 2026. The search strategy employed combinations of keywords and Boolean operators, including terms such as “neuromarketing,” “consumer neuroscience,” “pharmaceutical marketing,” “healthcare marketing,” “patient engagement,” “consumer behavior,” “electroencephalography,” “functional magnetic resonance imaging,” “eye tracking,” and “galvanic skin response.”

3.3. Eligibility criteria

Predefined inclusion and exclusion criteria were established to ensure consistency during study selection. In this work, studies were considered eligible if they investigated neuromarketing techniques, consumer neuroscience methodologies, or neuroscientific approaches relevant to healthcare and pharmaceutical applications. Also, eligible studies included empirical investigations, systematic reviews, narrative reviews, methodological studies, and conceptual articles published in peer-reviewed journals (in English). In contrast, studies were excluded if they were based solely on conference abstracts, editorials, opinion papers, commentaries, or non-peer-reviewed sources. Publications that were not directly relevant to neuromarketing, healthcare communication, or pharmaceutical marketing were also excluded.

3.4. Study selection process

The study selection process was conducted in a structured and sequential manner. Initially, all retrieved records were screened based on titles and abstracts to identify

potentially relevant studies. Then, duplicate records identified across databases were removed before screening. Articles meeting preliminary eligibility criteria underwent full-text assessment to determine their suitability for inclusion in the review. During full-text evaluation, studies were assessed for their relevance to neuromarketing methodologies, pharmaceutical marketing applications, healthcare communication strategies, ethical considerations, and the research objectives of the present review. The selection process emphasized methodological relevance, scientific quality, and contribution to knowledge about neuromarketing in healthcare and pharmaceutical contexts. Studies that passed all eligibility criteria were included in the final synthesis and thematic analysis.

3.5. Extraction and synthesis of data

To ensure systematic data collection from qualified investigations, a standardized data-extraction structure was developed. Relevant information was retrieved for each included publication, including authorship, year of publication, study design, employed neuromarketing techniques, participant characteristics, application domain, primary results, methodological strengths, and reported limitations. When accessible, more details about practical applications, regulatory impact, and ethical issues in the pharmaceutical industry were also recorded. After data extraction, studies were organized into theme groups that represent key aspects of neuromarketing research. These categories included: pharmaceutical branding and trust building; patient behavior and medication adherence; physician communication and engagement; neuromarketing technologies and methodologies; ethical and regulatory considerations; and healthcare applications and emerging technologies. In addition, recurrent patterns, emerging trends, research gaps, and prospects for further investigation were identified through a narrative thematic synthesis.

3.6. Assessment of quality

The included papers were carefully assessed using multiple quality indicators to promote methodological rigor. Also, the study design, sample characteristics, methodological transparency, clarity of data collection processes, suitability of analytical methods, and relevance to pharmaceutical neuromarketing were all considered in this evaluation. Major emphasis was devoted to the validity and reliability of neuromarketing techniques (EEG, fMRI, eye-tracking, GSR) and other neurophysiological data, as research with strong analytical techniques, transparent methodological reporting, and direct application in the pharmaceutical or medical fields yields strong evidentiary value.

3.7. PRISMA-based study selection framework

To increase transparency and reproducibility, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were applied for the identification and screening process of the literature. As described earlier, duplicates were removed, titles and abstracts were screened, full-text eligibility was evaluated, and records were finally included after retrieval from electronic databases. [Figure 1](#) summarizes the steps involved in selecting a study, including finding relevant literature, screening, assessing eligibility, and including it in the final review.

The steps of the framework are as follows:

(i) Step 1: Literature identification

The first step involved a thorough literature search across major scientific databases, including Google Scholar, PubMed, Scopus, and Web of Science. Relevant keywords, including “neuromarketing,” “consumer neuroscience,” “pharmaceutical marketing,” “healthcare marketing,” “patient engagement,” “consumer behavior,” “electroencephalography,” “functional magnetic resonance imaging,” “eye tracking,” and “galvanic skin response,” were applied individually and in combination with the help of Boolean operators. This step decreased selection bias and maximized retrieval of pertinent publications.

(ii) Step 2: Screening and eligibility assessment

In the second step, retrieved records were screened for title and abstract according to established inclusion and exclusion criteria. Research focused on consumer neuroscience, pharmaceutical marketing, healthcare communication, and neuromarketing techniques was considered suitable. In contrast, duplicate research, non-peer-reviewed sources, and publications that lacked a connection to the aims of this review were not included.

(iii) Step 3: Data extraction and classification

This step involved methodically compiling key data from relevant studies. The parameters obtained included employed neuromarketing technologies, target audiences, application domains, key findings, methodological traits, and disclosed limitations. Additionally, research was grouped by relevance to branding, healthcare marketing, patient behavior, pharmaceutical communication, and physician engagement.

(iv) Step 4: Thematic synthesis of evidence

Selected studies were classified into the following key thematic domains: pharmaceutical branding and trust building; patient behavior and medication adherence; physician communication and engagement; neuromarketing technologies and methodologies; ethical and regulatory considerations; and healthcare applications and emerging technologies.

(v) Step 5: Ethical and regulatory evaluation

This analytical step focused on ethical and regulatory issues, given the delicate nature of pharmaceutical marketing. In this context, informed consent, data privacy, protection of neurophysiological data, patient autonomy, subconscious influence, and adherence to the legal frameworks governing healthcare communication were thoroughly investigated.

(vi) Step 6: Critical analysis and research gap identification

This step involved careful analysis of methodological strengths and limitations across included studies. In this regard, constraints on sample size, the absence of standardized procedures, variability in neuromarketing strategies, and difficulties in interpreting neurophysiological data were given special attention. This step identified significant knowledge gaps that require further research.

(vii) Step 7: Future perspectives and conclusions

In the last step, the developed evidence was merged to formulate future research directions and practical recommendations for the responsible implementation of neuromarketing in the pharmaceutical field. Additionally, ethical governance, methodological standardization, integration of artificial intelligence (AI), and the creation of patient-centered communication strategies were top priorities.

Through this framework, 412 records were initially identified ([Figure 2](#)). Among these, 125 studies were included in the final qualitative synthesis after duplicate records were removed and eligibility criteria were applied.

4. Results

4.1. Neuromarketing in the pharmaceutical sector: An overview

Among diverse industries that adopt neuromarketing, the pharmaceutical sector possesses a unique combination of complexity, importance, and ethical stakes. Unlike fast-moving consumer goods, pharmaceutical products address life-and-death health issues. This involves multiple decision-makers (patients, physicians, caregivers) and is subject to tight regulatory oversight. Hence, marketing in the pharmaceutical space must navigate a highly informed audience of healthcare professionals, a vulnerable patient population, and strict rules on targeting, claims, and disclosures.^{32,33} By utilizing neuroscience-informed methods, pharmaceutical companies can better understand how patients process risk-benefit information, the emotional barriers that drive non-adherence, and how to craft communication that builds genuine trust. Similarly, neuromarketing can reveal how physicians evaluate complex clinical data under cognitive load, enabling clearer, more effective sales and educational materials.³⁴



Figure 1. Framework of study in the present review

Abbreviations: EEG: Electroencephalography; fMRI: Functional magnetic resonance imaging; GDPR: General Data Protection Regulation; GSR: Galvanic skin response; HIPAA: Health Insurance Portability and Accountability Act.

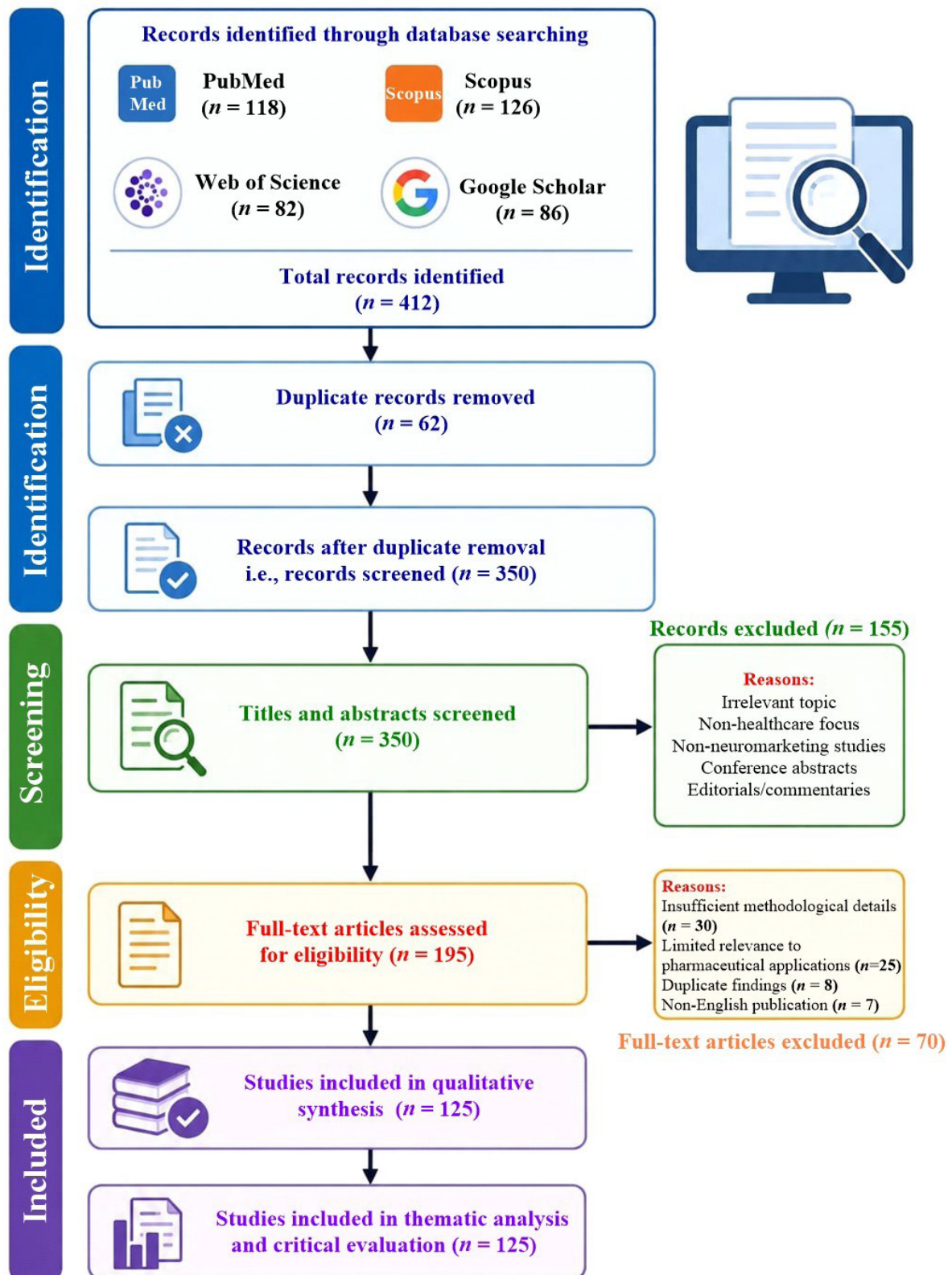


Figure 2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study selection process

Furthermore, pharmaceutical companies must ensure that neuromarketing-based strategies support informed consent and patient autonomy. These must also comply with strict advertising standards that forbid misleading claims and require balanced risk communication. Hence, neuromarketing in the pharmaceutical industry requires a more transparent and ethically aware approach.³⁵

4.2. Patient perspective: Emotions and adherence

One of the most difficult problems in healthcare is medication adherence. Ongoing research demonstrates that a significant number of people do not take their prescribed drugs, leading to worse health outcomes, longer hospital stays, and greater healthcare expenses. Therefore, rational appeals typically focus on adherence programs. These include informing patients about clinical benefits or providing dosage instructions. However, these methods frequently overlook significant emotional and cognitive factors that influence adherence behavior.³⁶ Neuromarketing is among the major methods for identifying and addressing these unconscious drivers. For example, fear of side effects cannot be purely rational but deeply emotional and remains linked to anxiety circuits in the brain. Hence, this can be measured through EEG and fMRI.³⁷ In addition, distrust of pharmaceutical companies stems from implicit biases, i.e., biases activated by branding elements. This can be identified through facial coding or GSR. By employing eye-tracking, companies can ensure that patient education materials highlight the most critical information. EEG can test videos regarding the explanation of drug regimens and evaluate their attention and effect on the reduction of anxiety.^{14,38} Additionally, packaging design can be optimized to communicate safety, application, and clarity. These reduce emotional and cognitive barriers to adherence. In conclusion, neuromarketing provides a way to formulate more patient-based adherence programs. This demonstrates that effective behavior modification requires consideration of information gaps, as well as emotional needs and cognitive biases.³⁹

4.3. Physician targeting and communication

Neuromarketing offers pharmaceutical marketers a more scientific way to design communications that respect the needs of physicians while improving clarity and persuasive effect. EEG can assess cognitive workload to ensure presentations are not overly complicated or confusing, while eye-tracking can indicate which sections of a clinical investigation are important or are ignored. Sales representatives can change their tone and approach using facial coding to identify subtle emotional responses to assertions.⁴⁰ For example, eye-tracking information may be utilized to develop booth layouts

that optimize accessibility and attention.⁴¹ To ensure they convey complex information without confusing viewers, interactive displays might be evaluated for their emotional impact and cognitive strain. Pharmaceutical businesses can enhance not only marketing results but also the sharing of important clinical knowledge by implementing scientifically verified physician communication tactics.⁴² To target physicians, neuromarketing should strive for transparency, participation, and trust building rather than manipulation. This will also ensure that busy physicians receive information they can use to better understand and assess their patients' needs.^{35,43}

4.4. Branding and trust in pharmaceuticals

Branding in the pharmaceutical sector differs from that in other consumer goods. Trust is a must for market access and patient consent, not just an advantage over rivals. Pharmaceutical products comprise significant health hazards and frequently life-or-death choices, in contrast to soft beverages or clothing. Therefore, emotional motivators of safety and trust are required as effective marketing strategies. In this regard, pharmaceutical companies can utilize advanced neuromarketing tools to identify and enhance these drivers.^{44,45} For example, visual branding components such as fonts, color schemes, and logos are not only artistic decisions but also convey professionalism and security.⁴⁶ Additionally, EEG and fMRI neuromarketing research revealed that specific colors and design components consistently activate brain regions linked to trust, including the medial prefrontal cortex, whereas eye-tracking can verify whether safety warnings and company certifications are truly noticed.⁴⁷ Furthermore, neuromarketing can improve packaging design to convey premium quality, safety, ease of use, and visual identification. Design alterations are possible using biometric data, including GSR and HRV. These tools can determine a packaging's ability to induce pleasure or stress.

Neuromarketing validation is beneficial for brand message.^{48,49} EEG and facial coding can describe the role of recordings of patient testimonials to elicit a true emotional response. These insights allow pharmaceutical businesses to generate emotionally compelling brands that adhere to the strictest ethical guidelines. In this context, honesty, clarity, and empathy are among the qualities that neuromarketing can help establish trust.⁵⁰

4.5. Navigating regulatory and ethical constraints

Pharmaceutical marketing is among the strictly regulated industries globally. Regulations are needed to safeguard patients from false promises, provide informed consent, and maintain the integrity of medical judgement. Globally, these regulatory frameworks are different. To maintain a

fair balance in direct-to-consumer advertising, the Food and Drug Administration (FDA) in the United States mandates that risks must be declared as clearly as benefits. In Europe, pharmacists are not permitted to market directly to consumers, whereas professional communications are expected.^{51,52} The implementation of neuromarketing in this context offers both opportunities and challenges that call for moral and methodical conduct. Neuromarketing reveals effective methods for influencing the triggers of subconscious fear, desire, and trust.⁵³ These insights can increase empathy and clarity in health communication, but they can be abused by circumventing logical analysis or exploiting weaknesses. Furthermore, ethical pharmaceutical marketers need to set internal policies to ensure that emotional appeals support well-informed decisions regarding patients. Another crucial area is data privacy.⁵⁴ In this regard, more sensitive biometric and neurophysiological data are gathered for neuromarketing research. Patients must be fully informed about the collection, storage, and use of their data to provide informed consent. When research involves patient data, businesses must abide by data privacy regulations, including the General Data Protection Regulation in Europe and the Health Insurance Portability and Accountability Act in the United States.⁵⁵ To promote openness, participant welfare, and the responsible use of findings, industry associations establish voluntary standards of conduct for ethical neuromarketing. By implementing these standards, pharmaceutical companies can demonstrate leadership and gain the trust of consumers, regulators, healthcare providers, and society.⁵⁶

Although neuromarketing can improve communication and patient engagement, it also raises significant ethical concerns. One major limitation is the lack of permission to engage in subtle manipulation by targeting subconscious processes. This can bypass the rational decision-making process, a critical factor in the pharmaceutical sector. In this field, patients may be in vulnerable emotional and psychological states. Additionally, issues of data privacy and informed consent become more complex when dealing with neurophysiological data, another highly sensitive data type. Meanwhile, there is a risk of unequal access to neuromarketing technologies. Large pharmaceutical companies gain a disproportionate advantage. Neuromarketing can elevate clarity in health communication, improve patient adherence, and support better healthcare outcomes. Therefore, the ethical acceptability of neuromarketing depends on transparency and on prioritizing patient welfare over commercial interests.

4.6. Emerging neuromarketing approaches and tools

A multidimensional framework showcasing a variety of neuromarketing methods and approaches used to conduct the behavioral study is presented, based on data from the neuromarketing literature. These neuromarketing resources and techniques were compiled for specific study contexts and unique criteria, such as the capture of brain electrical and metabolic signals. Electrical activity in the brain can be recorded and measured using steady-state probe topography⁵⁷, transcranial magnetic stimulation⁵⁸, EEG⁵⁹, magnetoencephalography (MEG)⁶⁰, and event-related potential.⁶¹ Additional methods, including positron emission tomography (PET)⁶², fMRI⁶³, and functional transcranial Doppler sonography⁶⁴, can reveal details of brain metabolic activity. Heart rate (electrocardiography), facial recognition, eye tracking, implicit association test, and GSR are methods for recording and analyzing physiological biometric activity, but they cannot record cerebral metabolic activity. The use of fMRI to capture and analyze brain activity in response to marketing communication inputs has grown in consumer behavioral research, providing insights into the decision-making process.⁶⁵ However, other alternative techniques might be deployed based on the research objective and available resources. [Figure 3](#) categorizes neuromarketing tools according to their ability to measure brain metabolic and electrical activity. The information from the content analysis and the literature is synthesized into an integrated conceptual framework that delves into consumer behavior through a neuromarketing lens. The framework is based on the theory of reasoned action, which depicts the interplay between consumers' purchase intentions and their actual behavior. This elucidates the relationship between stimulus and response, with neuromarketing effect positioned at the center of marketing activities. This model can potentially bridge the gap between the knowledge, attitude, and perception of a consumer by examining the effects of neuromarketing in specific circumstances⁶⁶ and identifying its importance as an additional factor that affects decision-making.⁶⁷ It complements the available knowledge domain of consumers, who have demonstrated a desire to buy and are emotionally, economically, and psychologically compatible with the subsequent stage of product purchase.

The framework (depicted in [Figure 4](#)) shows the logical relationship between purchase intention (an antecedent) and actual buying behavior (the outcome). The process underlying the production of antecedents and outcomes, specifically decision-making and the transformation of purchase intentions into actual buying behavior, is influenced by a number of variables.⁶⁸ The expansion

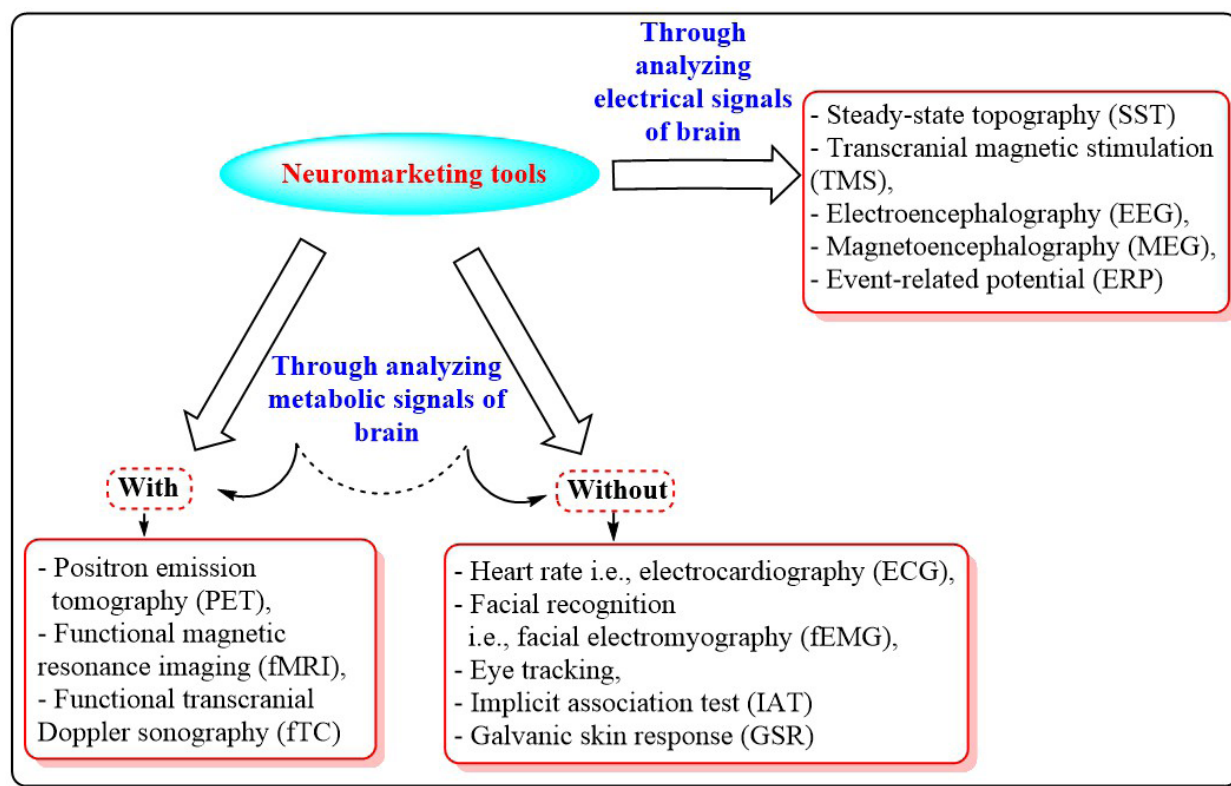


Figure 3. Major neuromarketing techniques employed in pharmaceutical and healthcare research. These techniques differ in aspects of temporal resolution, spatial resolution, cost, invasiveness, and applicability to healthcare communication, patient behavior assessment, and pharmaceutical marketing research.

of factors can be broadly categorized into two groups: intrinsic factors related to consumers and extrinsic factors rooted in the surrounding environment. Intrinsic factors, related to the consumer, such as attitudes, perceptions, and emotions, influence decision-making. Conversely, extrinsic factors, related to the environment, such as ethical concerns, privacy issues, and technology, critically affect the use of neuroscientific techniques in organizations. Intrinsic factors can moderate consumer responses, while extrinsic factors have a direct effect on consumer behavior, influencing purchase outcomes.^{1,69}

4.6.1. Neuromarketing tools: Advantages and limitations

The integration of the neuromarketing approach with the consumer behavioral domain facilitates strategic decision-making across diverse areas, such as market segmentation, product development, product packaging, and pricing strategy.⁷⁰ Businesses could leverage market segmentation based on consumer preferences and choices, accounting for biases in neurological characteristics, without reference to psychographics or demographics. In addition to product

development, neuromarketing can contribute to brand development by providing valuable insights to improve brand promotional campaigns⁷¹, reverberating through meticulous design considerations, from advertisement banners and hoardings to posters and media planning. Different neuromarketing tools offer distinct strengths and limitations for assessing consumer cognitive and emotional responses, i.e., relevant to pharmaceutical communication and medication adherence (Figure 5).

This section presents an anthology of typical marketing studies based on the fundamental neuromarketing principles, informing the suitability of the tools used to conduct research studies customized to specific user contexts (Table 2).⁷²⁻⁸⁰

Marketers and researchers have highlighted various neuromarketing techniques as functional strategies across different areas of marketing, considering their advantages and limitations. To improve customer insights, strategies are developed by combining traditional methodologies with neuroimaging and neuroscientific tools, as well as sensory marketing strategies.⁸¹ Neuroimaging techniques

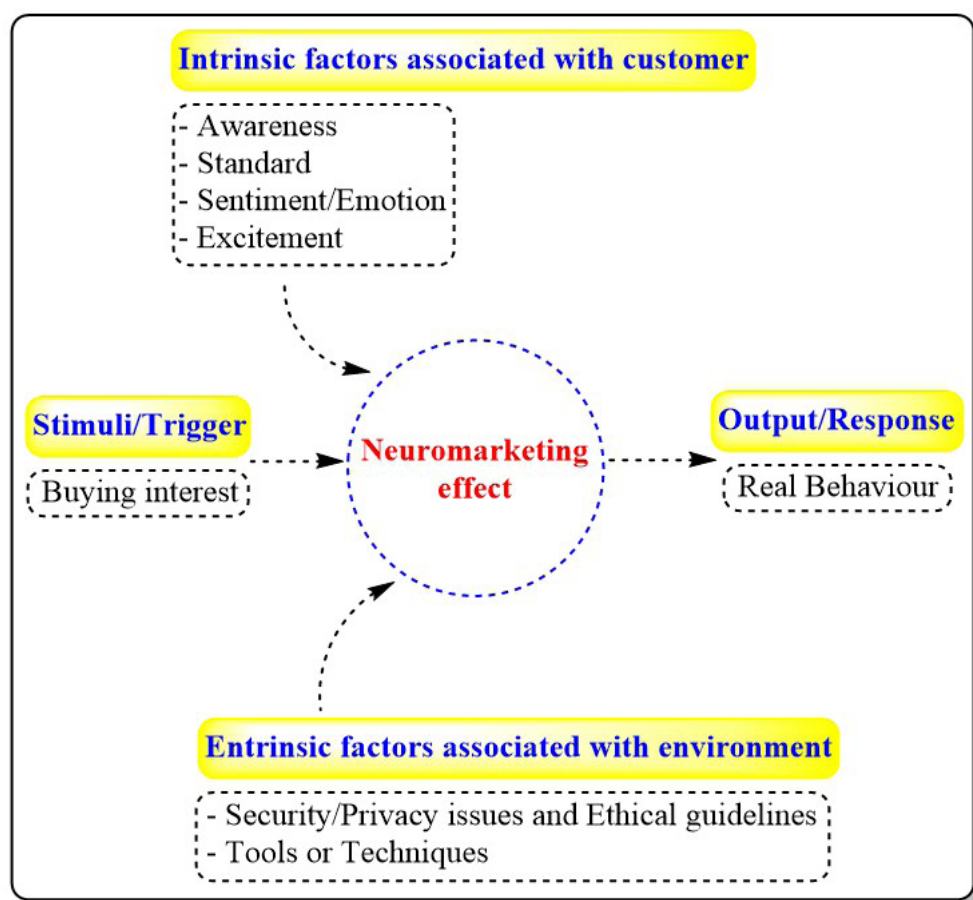


Figure 4. Theoretical framework of neuromarketing's effect on consumer responses. This figure presents the conceptual relationship among intrinsic characteristics of the consumer and external marketing stimuli that influence neural and psychological responses. These interactions determine consumer perceptions, preferences, purchase intentions, and final behavioral outcomes.

record the physiological metabolic activity of localized areas of the body, such as the brain, eyes, and skin, thereby serving as a strong indicator of consumers' choices and preferences. Table 3 highlights the advantages, location of effect, and limitations of neuromarketing tools.⁸²⁻⁸⁷

Table 2. Various neuroscientific tools used for specific user contexts

Entry	User context	Neuroscientific tool	Focus
1	Grocery items	EEG	Price ⁷²
2	Chocolate	fMRI	Product ⁷³
3	Advertisement	Eye tracking	Product ⁷⁴
4	Television advertisements	EEG	Product ⁷⁵
5	Consumer products	EEG	Price ⁷⁶

(Cont'd...)

Table 2. (Continued)

Entry	User context	Neuroscientific tool	Focus
6	Food	fMRI	Product ⁷⁷
7	Crackers	Eye tracking	Product ⁷⁸
8	Soft drinks and water-filled bottles	fMRI	Product ⁷⁹
9	Snacks	Eye tracking	Product ⁸⁰

Abbreviations: EEG: Electroencephalography; fMRI: Functional magnetic resonance imaging.

Neuromarketing is an emerging field that combines marketing strategies with insights from neuroscience to understand consumer decision-making. The foundation of neuromarketing is built on the "three-brain" model, which divides the brain into: (i) neocortex (thinking brain): responsible for logical analysis and rational decision-making; (ii) limbic system (emotional brain): influences

Technique	 Attention	 Emotion	 Trust	 Adherence influence	 Cost
EEG 	High	Moderate	Moderate	High	Low
fMRI 	Moderate	Very high	High	Moderate	Very high
Eye tracking 	Very high	Low	Low	High	Low
GSR 	Low	High	Moderate	Moderate	Low
Facial coding 	Moderate	High	Moderate	Low	Low

Figure 5. Comparative assessment of major neuromarketing techniques used in pharmaceutical marketing research. This figure compares electroencephalography (EEG), functional magnetic resonance imaging (fMRI), eye tracking, galvanic skin response (GSR), and facial coding in terms of their relative suitability for measuring attention, emotion, trust, adherence influence, and cost-effectiveness. Higher, moderate, and lower suitability are indicated by green, yellow, and red shading, respectively.

preferences subconsciously through emotions and feelings; and (iii) reptilian brain (old brain): govern survival instincts and basic functions, playing a key role in evaluating risks and needs.⁸⁸ Neuromarketing strategies include focusing on self-preservation, using contrasts to capture attention, emphasizing beginnings and endings, and relying on emotional and visual cues to make advertisements more memorable and impactful. Techniques such as fMRI and EEG analyses reveal brain regions involved in decision-making, such as the striatum and ventromedial prefrontal cortex, providing deeper insights for companies to enhance consumer engagement.^{82,83,89} The neuromarketing approach helps companies understand consumer behavior and create stronger emotional connections through targeted advertising strategies (Figure 6).

4.7. Role of neuromarketing in health services, including the pharmaceutical field

Pharmaceutical companies currently face greater obstacles in marketing and selling their products. Novel and inventive pharmaceutical products are constantly introduced to the market. The firm is profitable, which makes competition fierce.⁹⁰ Every business aims to stand out from the competition and attract customers by highlighting the advantages of its products. Advertising is crucial in this situation. In recent years, businesses have gained greater insights into their customers by leveraging a new science known as neuromarketing. To better understand how our central nervous system responds to marketing stimuli, neuromarketing employs certain medical procedures.⁹¹ The marketing expert can uncover expectations, feelings,

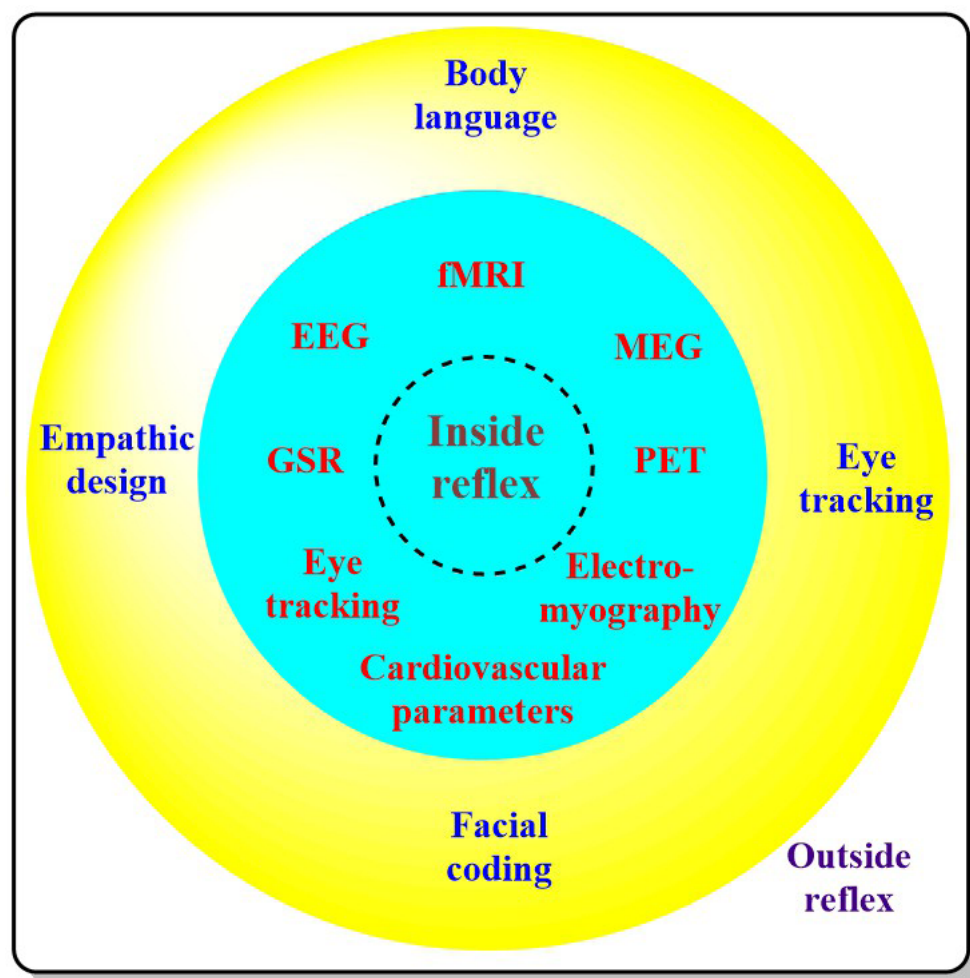


Figure 6. Inside and outside reflex neuromarketing techniques. Inside reflex techniques directly assess neural activity in the brain, while outside reflex techniques evaluate peripheral physiological and behavioral responses linked to the consumer's cognition, emotion, and decision-making processes. Abbreviations: EEG: Electroencephalography; fMRI: Functional magnetic resonance imaging; GSR: Galvanic skin response; MEG: Magnetoencephalography; PET: Positron emission tomography.

and emotions by employing neuromarketing strategies. Neuroimaging and other neurological techniques have become common research tools in economic, social, and medical sciences. However, little information is available on the use of neuromarketing strategies by pharmaceutical corporations. Many businesses would rather not reveal such information due to ethical concerns. Neuromarketing typically examines the effects of eye tracking, GSR, EEG, and fMRI. They are chosen based on their cost and possible outcomes. The brain is the most fascinating subject for study and the most intricate organ in the human body. When researching participants with varying ages or educational levels, marketing specialists collect distinct images because synapses change with experience and

learning.⁶⁵⁻⁶⁷ Neuromarketing research employs several methodologies to examine health concerns more precisely. In this regard, fMRI is a medical technique that measures blood flow and oxygen levels to assess brain activity. Each part of the brain requires more oxygen during active states.⁹² EEG records and monitors electrical activity in the brain.⁹³ Meanwhile, steady-state topography records and analyzes brain activity.⁹⁴ Moreover, MEG uses a magnetic field to measure brain activity. Unlike functional techniques such as fMRI, it directly measures brain activity. Its spatial and temporal resolution is significant.⁹⁵ The number of breaths taken per minute is known as the respiratory rate. Heart rate is the average number of heartbeats per minute, while a pupilometer is a device used to assess the dilation or

Table 3. Advantages, location of effect, and limitations of neuromarketing techniques

Neuromarketing tool	Benefits	Location of effect	Limitations
Electroencephalography (EEG) ⁸²	- Evaluates brain signals at the millisecond scale	- Electrical activity in specific brain regions	- It is difficult to identify signals from certain brain regions - Deeper brain structures cannot be examined
Functional magnetic resonance imaging (fMRI) ⁸³	- Address activities of tiny regions - Evaluate and distinguish adjacent signals - Examine the entire brain	- Regional cerebral oxygen consumption	- Physically challenging - Costly
Eye tracking ⁸⁴	- More sophisticated data can be obtained by combining visual attention assessment with pupillometry	- Diameter of the pupil - Attention to the subject	- It overlooks thoughts, feelings, and inferences
Transcranial magnetic stimulation (TMS) ⁸⁵	- May be used to demonstrate causality	- Temporary suppression of local brain activity	- Solely concentrates on how the surface brain region functions
Biometrics: Pupil relaxation, heart rate, skin conductance response (SCR) ⁸⁶	- Easy and thoroughly verified	- Heart rate - Pupil dilation	- Cannot differentiate between positive and negative arousal
Facial electromyography (fEMG) ⁸⁷	- Continuous observation of subconscious emotional reactions to continuous sensory input - Software for automatically encoding pictures of faces	- Facial affective coding	- It affixes electrodes to the face directly

relaxation of participants' pupils in response to a visual stimulus.⁹⁶ In addition, GSR quantifies and records the electrical events of the skin, which vary with the amount of moisture present.⁹⁷ The eye-tracking technique monitors eye gaze, while psychophysiological stress reactions during human speech are captured by voice analysis.⁹⁸ Each neuromarketing technology offers distinct advantages and limitations in terms of temporal and spatial resolution, cost, invasiveness, and applicability in healthcare research. A comparative summary is presented in [Table 4](#).

4.8. Applications of neuromarketing in pharmaceuticals

Neuromarketing directly measures brain activity, physiological responses, and unconscious activities. Meanwhile, client confidence, ethics, and their regulation are particularly important in the pharmaceutical industry. Neuromarketing has become a contentious yet promising method for studying decision-making in patients and healthcare professionals.⁹⁹ Neuromarketing examines neural and emotional responses to marketing stimuli using methods such as eye tracking, EEG, fMRI, facial coding, and GSR, in contrast to conventional marketing research, which relies on survey groups.¹⁰⁰ Pharmaceutical businesses may leverage this to their advantage by optimizing branding, advertising, and packaging design to appeal to subconscious factors that influence trust and choice. Pharmaceutical firms frequently face competition

from identical products in highly competitive markets. By testing branding components such as logos, colors, package designs, and messages at a subconscious level, neuromarketing enables businesses to determine the triggers that elicit feelings of efficacy, safety, and trust.^{47,101} For example, consumers can associate cleanliness and dependability with cool hues and specific geometries. Despite being highly regulated, direct-to-consumer advertising is a vital channel in certain economies such as the United States. Without violating moral principles, neuromarketing can evaluate memory encoding and emotional involvement during advertisement exposure to improve message clarity and effectiveness.¹⁰² Medication non-adherence remains a major problem in healthcare. By leveraging knowledge of anxiety and relief reactions, neuromarketing can be applied to create more emotionally compelling and convincing patient education materials. Adherence rates can be increased by packaging and directions that reduce cognitive burden and foster a stronger emotional bond.^{36,103}

Despite these advantages, there are serious ethical issues with neuromarketing in the pharmaceutical industry. Patients frequently make decisions while in pain or under stress. If neuromarketing is applied carelessly, it could exploit these weaknesses and prioritize sales over people's health. Because neurological and physiological data are confidential, there are privacy and safety

issues. Furthermore, small sample sizes and excessive interpretation of brain imaging data are common problems during neuromarketing research. To ensure that results are repeatable and significant, future studies must employ strong experimental procedures. Traditional approaches should not be replaced by neuromarketing, even though it can reveal unconscious drivers. For comprehensive consumer insights, future research should integrate neurological and physiological data with self-reported and sales data. Moreover, the generalizability of neuromarketing findings must be investigated across a range of patient demographics, given differences in emotional reactions to marketing stimuli across cultures and age groups. Moreover, integrating neuroscientific measures into pharmaceutical marketing can be conceptualized as a pathway linking neurophysiological inputs to communication outcomes via cognitive and emotional mechanisms (Figure 7).

5. Discussion

5.1. Interpretation of key findings

Several findings from this review indicate that neuromarketing offers a valuable framework for understanding the subconscious cognitive and emotional mechanisms underlying the pharmaceutical decision-making process. Unlike conventional marketing approaches, which primarily rely on self-reported responses, neuromarketing techniques provide objective measures

of attention, emotional engagement, trust formation, memory encoding, and risk perception.¹⁰⁴⁻¹⁰⁷ Furthermore, the reviewed evidence suggests that tools such as EEG, fMRI, eye tracking, and GSR can generate meaningful insights into patient behavior, physician engagement, and perceptions of pharmaceutical brands. These technologies enable the development of communication strategies better aligned with the cognitive and emotional needs of target audiences.^{108,109} To provide a comprehensive overview of the evolution and application of neuromarketing in healthcare and pharmaceutical contexts, representative studies employing various neuroscientific methodologies are summarized in Table 5.

5.1.1. Medicinal and therapeutic challenges

Despite its potential, several obstacles persist to the use of neuromarketing in therapeutic settings. In this regard, people with neurological illnesses, psychiatric disorders, chronic diseases, or cognitive impairments can possess altered neurophysiological responses. This renders it more difficult to interpret neuromarketing data. Moreover, improved therapeutic outcomes or long-term adherence are not consistently correlated with emotional responses to pharmaceutical commercials.^{110,111} Another difficulty is finding a balance between ethical duties to present evidence-based medical information and persuasive communication. Furthermore, over-reliance on emotional triggers can unintentionally affect preferences for treatment

Table 4. Comparative analysis of neuromarketing technologies used in healthcare and pharmaceutical research

Technique	Major application	Strengths	Limitations	References
EEG	Attention, engagement, emotional processing	High temporal resolution, portable, relatively inexpensive	Low spatial resolution	21,47,78,82,98
fMRI	Reward processing, trust, decision-making	Excellent spatial resolution and whole-brain assessment	Expensive, complex infrastructure	15,83,89
Eye tracking	Visual attention and information processing	Non-invasive, easy interpretation	Cannot directly assess emotions	41,78,84
GSR	Emotional arousal assessment	Simple and cost-effective	Low specificity of emotional states	97,98
HRV	Stress, cognitive workload, and engagement	Real-time physiological monitoring	Influenced by multiple physiological factors	96,98
Facial coding/fEMG	Emotional expression analysis	Captures unconscious emotional responses	Cultural variability and interpretation challenges	13,87
PET	Brain metabolism assessment	Functional metabolic imaging	Radiation exposure and high cost	62,83
MEG	Neural activity mapping	Excellent temporal resolution	Limited availability and very costly	60,95
Hybrid multimodal systems	Integrated cognitive-emotional assessment	Improved validity through data triangulation	Complex analysis and implementation	21,78,98

Abbreviations: EEG: Electroencephalography; fEMG: Facial electromyography; fMRI: Functional magnetic resonance imaging; GSR: Galvanic skin response; HRV: Heart rate variability; MEG: Magnetoencephalography; PET: Positron emission tomography.

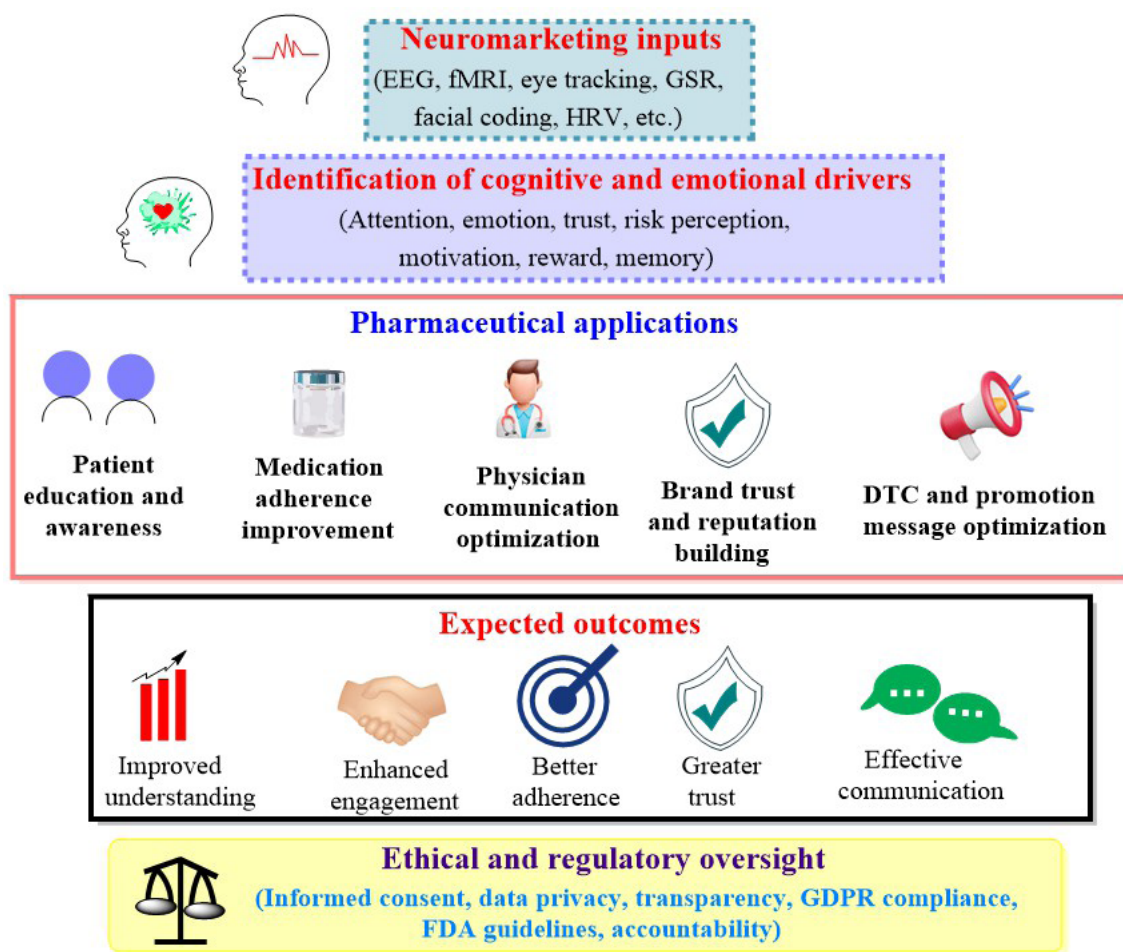


Figure 7. Conceptual framework to illustrate the application of neuromarketing in decision-making and pharmaceutical communication. This figure reveals that neuromarketing techniques generate insights into cognitive and emotional drivers. This influences patient and physician responses, enabling optimization of patient education, medication adherence, physician communication, brand trust, and promotional strategies while operating within ethical and regulatory boundaries.

Abbreviations: DTC: Direct-to-consumer; EEG: Electroencephalography; FDA: Food and Drug Administration; fMRI: Functional magnetic resonance imaging; GDPR: General Data Protection Regulation; GSR: Galvanic skin response; HRV: Heart rate variability.

without assisting in formulating well-informed therapeutic decisions. As a result, neuromarketing tactics need to support well-established concepts of patient-specific care and evidence-based medicine.^{112,113}

5.1.2. Operational and implementation challenges

Currently, numerous operational obstacles prevent neuromarketing from being widely adopted in pharmaceutical companies. Sophisticated neuroimaging technologies (e.g., fMRI, PET, and MEG) necessitate a significant financial investment, more qualified personnel, and specialized infrastructure.^{105,114} Meanwhile, relatively accessible methods, such as EEG and eye tracking, require proficiency in data interpretation, signal capture, and

artifact reduction.^{106,109} The lack of widely recognized methodological standards renders it difficult to compare results among research and healthcare environments.^{114,115} Moreover, the complexity of implementation is increased by regulatory restrictions on the storage of neurophysiological data, informed consent, and patient privacy.^{116,117} These operational constraints can limit adoption to major pharmaceutical enterprises unless cost-effective, standardized approaches become more widely available.^{114,115}

5.1.3. Surgical and clinical communication challenges

Although neuromarketing has primarily been explored in the promotion of pharmaceutical and patient education,

Table 5. Representative neuromarketing studies and their key contributions

Reference	Year	Study type	Study focus	Major findings	Relevance to pharmaceuticals
Fugate ³	2007	Conceptual review	Foundations of neuromarketing	Established integration of neuroscience and marketing	Theoretical basis for pharmaceutical neuromarketing
Ariely & Berns ¹⁵	2010	Review	Neuroimaging in marketing	Highlighted opportunities and limitations of neuromarketing	Ethical and methodological considerations
Javor et al. ⁵³	2013	Review	Consumer neuroscience	Explained the neural mechanisms underlying consumer decisions	Healthcare communication and patient behavior
Smidts et al. ²⁸	2014	Review	Consumer neuroscience development	Advanced application of neuroscience in marketing research	Framework for healthcare marketing research
Karmarkar & Plassmann ⁸⁹	2019	Review	Consumer neuroscience evolution	Integrated behavioral and neuroscientific perspectives	Pharmaceutical decision-making processes
Rawnaque et al. ⁹⁸	2020	Systematic review	Neuromarketing technologies	Summarized advances in EEG, fMRI, eye tracking, and biometrics	Methodological guidance
Demir ⁹⁹	2022	Systematic review	Healthcare marketing applications	Identified opportunities and ethical challenges	Direct healthcare relevance
Khondakar et al. ⁸²	2024	Systematic review	EEG-based neuromarketing	Evaluated recent EEG methodologies and applications	Patient engagement and communication assessment
Alsharif & Mohd Isa ⁸³	2024	Review	fMRI in neuromarketing	Demonstrated utility of fMRI in consumer behavior analysis	Branding and trust evaluation
Ramsøy et al. ²⁵	2019	Review	Neuroscience and AI in healthcare communication	Highlighted AI-assisted decision support and optimization of communication	Future pharmaceutical applications

Abbreviations: AI: Artificial intelligence; EEG: Electroencephalography; fMRI: Functional magnetic resonance imaging.

its application within surgical and broader clinical settings remains relatively underdeveloped.^{110,112} Surgical decision-making generally involves more emotional stress and risk-benefit assessment by patients and caregivers.¹¹⁸ Understanding cognitive responses to informed consent documents, preoperative counseling materials, and postoperative educational resources provides opportunities to improve patient profiling and engagement.^{118,119} However, ethical concerns become significant in these contexts because patients facing surgical interventions can be psychologically vulnerable.^{113,118} As a result, the use of subconscious behavioral insights must be carefully regulated to ensure that clinical autonomy, informed consent, and shared decision-making remain protected. Therefore, future research should investigate the role of neuromarketing techniques in supporting transparent communication without introducing unintended bias into clinical decisions.^{110,118,119}

5.1.4. Neuroethical challenges and regulatory considerations in pharmaceutical neuromarketing

Unlike traditional market research approaches that primarily assess conscious preferences and self-reported attitudes, neuromarketing technologies aim to investigate subconscious cognitive and emotional processes that can influence the decision-making process.¹⁰⁴⁻¹⁰⁷ Therefore, ethical evaluation of pharmaceutical neuromarketing requires careful consideration of patient autonomy, vulnerability, commercial influence, transparency, and regulatory accountability.^{113,116} One of the most significant neuroethical concerns involves the preservation of patient autonomy. Here, respect for autonomy is a fundamental principle of healthcare ethics and requires that individuals make decisions freely, with adequate knowledge of available information. Furthermore, neuromarketing techniques can identify subconscious emotional triggers that can create tension between persuasive communication

and autonomous decision-making.¹¹⁸⁻¹²⁰ Although improved engagement with health information can be beneficial, concerns arise when communication strategies are designed to influence behavior through unconscious mechanisms rather than to support informed, rational evaluation of treatment options. Therefore, the ethical acceptability of neuromarketing depends on whether it increases patient knowledge or merely exploits cognitive biases to influence healthcare choices.^{113,120} The vulnerability of patient populations represents another critical ethical consideration. Unlike consumers who purchase ordinary commercial products, patients usually make decisions under conditions of illness, uncertainty, emotional distress, or cognitive burden.¹¹⁹ Furthermore, individuals affected by chronic diseases, neurological disorders, psychiatric conditions, or life-threatening illnesses can be susceptible to emotionally persuasive messaging.^{118,118} Hence, the application of neuromarketing techniques within pharmaceutical contexts necessitates more ethical scrutiny to ensure that vulnerable individuals are not subjected to inappropriate influence or manipulation.¹²⁰ Communication strategies should prioritize patient welfare, health literacy, and shared decision-making.^{118,119} Moreover, commercial influence and conflicts of interest also warrant careful examination. Pharmaceutical companies operate in competitive markets and have legitimate interests in promoting products and improving the effectiveness of communication. However, using neuroscientific insights to optimize persuasive messaging raises concerns regarding the balance between commercial goals and patient-centered care. The ethical boundary between persuasion and manipulation remains a subject of ongoing debate within neuroethics.^{113,120} Therefore, persuasion can be considered ethically acceptable when it facilitates understanding of scientifically accurate information and supports beneficial health behaviors. In contrast, manipulation occurs when communication intentionally exploits cognitive vulnerabilities or emotional biases. Hence, management of this distinction is essential to ensure responsible implementation of neuromarketing strategies in healthcare settings.^{113,118-120}

Another important concern is the privacy and ownership of neurophysiological data. Various technologies, such as EEG, fMRI, eye-tracking, facial coding, and biometric monitoring, generate more sensitive information regarding cognitive states, emotional responses, attention patterns, and behavioral tendencies.¹⁰⁶⁻¹⁰⁹ In contrast to conventional demographic or survey data, neurophysiological information can reveal intimate aspects of an individual's cognition and emotional functioning.^{113,120} Therefore, ethical governance requires robust safeguards for data collection, storage, analysis,

sharing, and secondary use.¹¹⁷ In addition, transparency regarding data handling procedures, informed consent requirements, anonymization practices, and cybersecurity measures is essential to protect individual rights and maintain public trust. Existing frameworks, such as data protection regulations, healthcare privacy legislation, pharmaceutical advertising standards, and biomedical research ethics guidelines, provide important safeguards but cannot fully address the unique ethical implications of neuromarketing technologies.^{116,120} Future regulatory frameworks should establish clear standards regarding transparency, accountability, consent procedures, data governance, and the permissible role of neuroscientific techniques in healthcare communication.^{113,117,120} The ethical acceptability of pharmaceutical neuromarketing should be evaluated based on its capacity to promote patient welfare, support informed decision-making, and strengthen healthcare communication, while respecting autonomy, privacy, dignity, and justice.¹¹⁶⁻¹¹⁸ Future development in this field will require ongoing collaboration among neuroscientists, healthcare professionals, ethicists, regulators, patient advocacy groups, and pharmaceutical stakeholders to ensure that technological innovation remains aligned with fundamental ethical principles.¹¹⁰ Although pharmaceutical neuromarketing provides significant opportunities to improve healthcare communication, its implementation must be balanced against ethical, privacy, and regulatory concerns through appropriate governance mechanisms (Figure 8).

5.1.5. Methodological limitations of current neuromarketing research

The present review identified several methodological challenges that restrict the translation of neuromarketing findings into pharmaceutical practice.^{105,115} Almost all studies used relatively small sample sizes due to the high cost and technical complexity of neuroimaging methods. In addition, considerable variability existed across experimental design, stimulus presentation, participant selection, outcome measurement, and data interpretation.¹¹⁴ Many studies depended on reverse inference, in which activation of specific brain regions was interpreted as evidence of particular psychological states. These interpretations should be approached with care, as neural responses often reflect multiple overlapping cognitive processes. Thus, standardization of study protocols remains a critical need for future research.^{115,121}

5.2. Future research directions

In the future, pharmaceutical neuromarketing will be shaped through technological advancements in AI, machine learning, wearable biosensors, digital

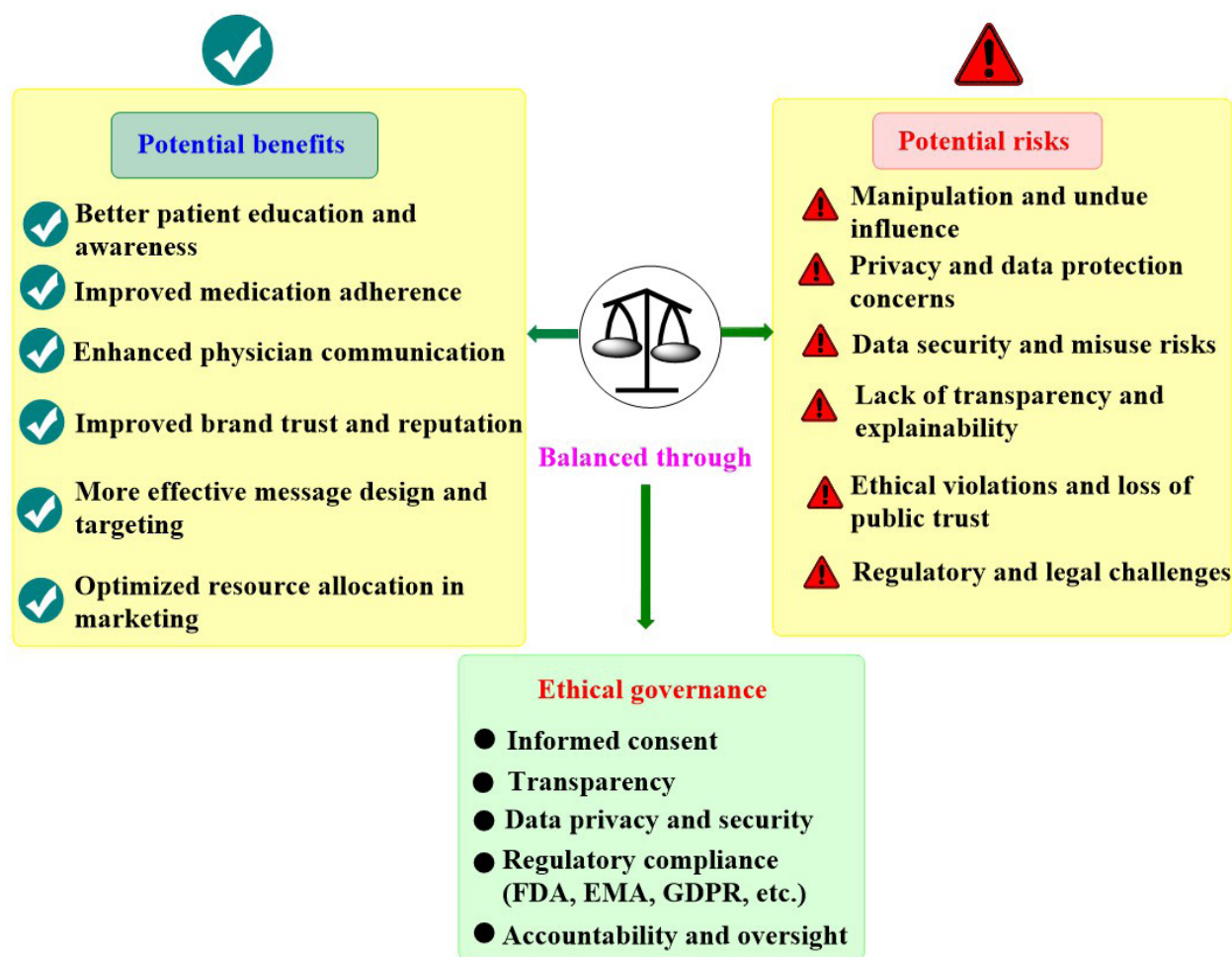


Figure 8. Risk–benefit assessment framework for pharmaceutical neuromarketing. This figure summarizes potential benefits, including improved patient education, medication adherence, communication with the physician, and effectiveness of the message, along with potential risks such as manipulation, privacy concerns, data misuse, lack of transparency, and regulatory challenges. In this context, ethical governance mechanisms are presented as safeguards for responsible implementation.

Abbreviations: EMA: European Medicines Agency; FDA: Food and Drug Administration; GDPR: General Data Protection Regulation.

therapeutics, and real-time behavioral analytics.^{122–124} In this regard, emerging multimodal approaches that integrate EEG, eye tracking, facial expression analysis, HRV, and digital behavioral data can provide a detailed understanding of patient engagement and decision-making in healthcare. Furthermore, personalized health communication platforms can adapt educational content to individuals' cognitive and emotional profiles, thereby increasing treatment adherence and health literacy.^{122,123} Additionally, development of standardized ethical systems, international regulatory guidelines, and robust validation studies will be critical to ensure responsible implementation.^{113,115,120} Future investigations should focus on multicenter, longitudinal, and cross-cultural studies to

establish the clinical relevance, reproducibility, and societal impact of neuromarketing applications within healthcare and pharmaceutical systems.^{114,124}

Neuromarketing possesses considerable potential to transform pharmaceutical communication and healthcare engagement.^{104–107,122} However, substantial methodological, ethical, regulatory, and translational challenges remain unresolved.¹²⁰ Therefore, responsible integration of neuroscientific insights into pharmaceutical practice requires careful balancing of commercial objectives with patient welfare, scientific validity, and societal trust.^{112,113,120} Continued collaboration among neuroscientists, healthcare professionals, pharmaceutical stakeholders, ethicists, and regulatory authorities will be essential to

maximize benefits while minimizing potential risks.^{120,124}

5.3. Implications for pharmaceutical marketing practice

Neuromarketing should not be considered solely as a commercial optimization tool; rather, it represents a mechanism to improve healthcare communication.¹¹⁰ Properly applied neuromarketing approaches can increase the availability of patient education materials, strengthen medication adherence programs, improve physician-focused scientific communication, and support transparent risk–benefit information.^{112,122} By prioritizing patient welfare and evidence-based communication, pharmaceutical organizations can leverage neuromarketing insights to foster trust, improve health literacy, and thereby contribute to better healthcare outcomes.^{120,123}

Neuromarketing offers significant opportunities to enhance pharmaceutical communication by enabling a deeper understanding of patients' and healthcare professionals' subconscious cognitive and emotional responses. Generally, conventional surveys fail to capture implicit attitudes and hidden decision-making processes, while neuromarketing tools can evaluate attention, memory formation, trust development, emotional engagement, and risk perception.^{104–107} These insights can facilitate the design of patient-centered educational materials, optimize direct-to-healthcare-professional communications, and improve medication adherence strategies.^{110,112,122,123} Furthermore, neuromarketing

can support the development of more effective health awareness campaigns by identifying communication formats that maximize information retention while minimizing cognitive overload.^{122,123} Moreover, integrating AI with real-time biometric monitoring can expand the ability to personalize healthcare communication and improve treatment outcomes.^{122–125} Table 6 enlists major opportunities, implementation challenges, and future directions of neuromarketing within pharmaceutical and healthcare systems.

5.4. Critical appraisal of included studies

Various studies included in this review demonstrate the growing potential of neuromarketing techniques for understanding cognitive, emotional, and behavioral responses relevant to decision-making in pharmaceutical and healthcare domains. However, a critical evaluation of the available evidence reveals several methodological limitations that should be considered when interpreting reported findings. One of the most commonly observed limitations is the use of relatively small sample sizes. Many neuromarketing studies employ participant cohorts ranging from fewer than 20 to 100 individuals due to the high cost, technical complexity, and logistical demands associated with neuroimaging and physiological monitoring technologies.^{21,47,78,98} While these studies provide valuable preliminary insights, small sample sizes can reduce statistical power and limit the generalizability of findings across diverse patient and healthcare populations.^{89,112} Significant heterogeneity was also

Table 6. Applications, opportunities, challenges, and future directions of neuromarketing in pharmaceutical and healthcare systems

Application	Opportunities	Challenges	Future prospects	References
Patient education	Improved understanding of treatment information	Ethical concerns regarding persuasion	Personalized educational platforms	29,36,39,113
Medication adherence	Enhanced adherence and behavioral engagement	Individual variability in emotional responses	AI-assisted adherence prediction models	36,39,103,122
Pharmaceutical branding	Improved trust and brand recognition	Risk of manipulation and bias	Ethical brand-development strategies	44,47,50,101
Physician communication	Improved knowledge transfer and reduced cognitive burden	Information overload	Adaptive scientific communication systems	40,41,42
Digital health marketing	Real-time consumer engagement	Privacy and data-security concerns	AI-driven personalized communication	113,122,123
Clinical communication	Improved patient engagement and informed decision-making process	Vulnerable patient populations	Decision-support communication tools	110,118,119
Healthcare services	Service optimization and patient-centered care	Regulatory and implementation barriers	Integrated healthcare communication ecosystems	29,43,113
Neuroethical governance	Improved transparency and trust	Autonomy, consent, and privacy concerns	Standardized ethical and regulatory frameworks	43,113,116,120

Abbreviation: AI: Artificial intelligence.

observed in study designs, participant characteristics, experimental protocols, outcome measures, and analytical approaches. Researchers have utilized a wide variety of neuromarketing tools, including EEG, fMRI, eye tracking, GSR, HRV, facial coding, and hybrid multimodal systems.^{21,47,78,82,98} Differences in experimental methodologies and reporting standards make direct comparison across studies challenging and may contribute to inconsistencies in reported outcomes. Another important limitation concerns the risk of selection bias and population bias. A considerable proportion of studies rely on convenience sampling, university students, healthy volunteers, or geographically restricted populations.^{30,72,78,80} Consequently, the resulting findings may not accurately reflect responses of broader patient populations, healthcare professionals, or individuals from diverse cultural and socioeconomic backgrounds. Furthermore, interpretation bias represents a recurring challenge within neuromarketing research. Several studies rely on reverse inference, in which the activation of specific brain regions is interpreted as evidence of distinct psychological states, such as trust, preference, attention, and purchase intention.^{15,112} Since individual brain regions participate in multiple cognitive processes, neurophysiological responses should be interpreted cautiously and in conjunction with behavioral and contextual data. Publication bias may also influence the available evidence base, as studies reporting significant or positive findings are generally more likely to be published than studies with null or inconclusive results. This tendency can contribute to overestimating the effectiveness and practical utility of neuromarketing approaches in pharmaceutical and healthcare contexts.^{21,89,112} Despite these limitations, the reviewed literature consistently demonstrates that neuromarketing methodologies can provide valuable complementary insights that are often inaccessible through traditional survey-based approaches alone.^{14,17,25,89,98} Future investigations should prioritize larger sample sizes, multicenter collaborations, standardized methodological protocols, longitudinal study designs, and integration of neurophysiological findings with clinically meaningful healthcare outcomes to strengthen the robustness and translational value of the evidence base.^{29,43,89,113}

6. Critical analysis of neuromarketing in pharmaceuticals

Neuromarketing offers innovative tools for understanding the subconscious decision-making process. However, its use in the pharmaceutical sector is constrained by several critical limitations. One of the primary concerns is reliance on small sample sizes, given the high cost and complexity of neuroimaging techniques (e.g., fMRI).

This raises questions regarding statistical robustness and external validity. Moreover, many neuromarketing studies rely on reverse inference. To provide evidence of particular psychological states, the interpretation of activation in specific brain regions is carried out. This approach can yield misinterpretation of results, especially in complex healthcare decision-making situations. Another major concern is the lack of standardized experimental protocols across studies. These include variability in stimuli, measurement techniques, and data analysis methodologies. This heterogeneity reduces comparability and limits the ability to draw general conclusions.

In a pharmaceutical context, decision-making is influenced by emotional and cognitive factors, clinical evidence, regulatory guidelines, and the expertise of the physician. Therefore, neuromarketing should be observed as a complementary tool. Future research should focus on integrating neuromarketing data with behavioral, clinical, and real-world evidence to enhance its applicability and reliability. This review contributes to existing literature by: (i) providing a focused compilation on implications of neuromarketing in the pharmaceutical sector; (ii) providing a critical assessment of limitations in current studies; (iii) highlighting ethical and regulatory challenges; and (iv) identifying research gaps and predicting future research directions.

Future research should focus on large-scale, multi-center studies to improve generalizability. Furthermore, standardization of neuromarketing approaches is required to enhance reproducibility. In addition, integrating neurophysiological data with behavioral and clinical results will yield more detailed insights. Cross-cultural studies are required to understand variations in emotional and cognitive responses across populations. Finally, the development of ethical frameworks specific to pharmaceutical neuromarketing is required to ensure responsible application.

7. Conclusion

Neuromarketing provides the pharmaceutical industry with an advanced, science-based strategy to decode the subconscious processes that drive patient and healthcare professional decisions. Through techniques such as fMRI, EEG, and eye tracking, which measure brain activity and physiological responses, pharmaceutical companies can determine whether aspects of their branding, messaging, or packaging designs implicitly inspire safety, efficacy, and consumer trust. Enhancing patient education resources, encouraging drug adherence through emotionally charged interactions, and improving direct-to-consumer advertising within controlled parameters can all be achieved

through neuromarketing. Furthermore, neuromarketing provides healthcare professionals with insights to optimize intricate scientific presentations and marketing collateral, increasing trust and clarity without being manipulative. However, using neuromarketing in the pharmaceutical industry necessitates strict ethical guidelines. Patients are in delicate states of mind and may be particularly open to subtle emotional stimuli. If neuromarketing is employed solely to increase sales without prioritizing patient welfare, this raises questions about inappropriate influence or exploitation. Because brain and physiological data are extremely personal, data privacy becomes especially crucial. Pharmaceutical companies are required to obtain informed consent, maintain rigorous privacy measures, and ensure transparency in the collection and application of data. Future studies should use larger, more varied samples and combine neurophysiological data with behavioral and self-report measures to increase methodological rigor. While industry, regulators, and researchers must work together to develop ethical frameworks specific to pharmaceutical marketing, cross-cultural investigations are needed to ensure the universality of the findings. Finally, the potential of neuromarketing to enhance health outcomes can only be realized if it is used sensibly, leveraging the latest research to empower and educate both patients and healthcare professionals.

Acknowledgments

None.

Funding

None.

Conflict of interest

The authors declare no conflict of interest.

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Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Not applicable.

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