



Neuromarketing as Emerging Marketing Tool in Pharmaceutical Domain: Comprehensive Overview on Applications and Safety Concerns

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Highlights

- This review discusses neuromarketing in pharmaceutical marketing, focusing on tools like fMRI, EEG, and eye-tracking to decode subconscious responses.
- The analysis shows these tools enhance marketing efficacy but raise ethical and regulatory challenges, especially in healthcare.
- The article emphasizes neuromarketing's transformative potential while advocating for a balanced approach that safeguards consumer autonomy and improves evidence-based practices.

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ABSTRACT

Background: Neuromarketing is an interdisciplinary approach generated by integrating neuroscience, psychology, and marketing. It has emerged as a powerful tool to understand and influence consumer behavior by analyzing neural responses to marketing stimuli. In the pharmaceutical sector, decision-making is complex and often emotionally charged; neuromarketing offers novel insights into patient and healthcare professional engagement and brand communication strategies.

Methods: This review comprehensively discusses the role of neuromarketing in different fields, including pharmaceutical marketing, with a focus on the utility of neuroimaging and psychophysiological tools such as fMRI, EEG, eye-tracking, galvanic skin response, and others to decode subconscious responses to pharmaceutical advertisements, packaging, and digital campaigns. A critical analysis of existing literature from healthcare and related sectors was conducted.

Results: The reviewed literature highlights the significance of these tools in enhancing the efficacy of marketing strategies and promoting ethical consumer interactions. The review also addresses safety concerns associated with neuromarketing practices, including data privacy, informed consent, and the potential for manipulation. The integration of neuroscientific data into marketing raises important ethical and regulatory challenges, especially in the health sector. In addition, future research directions emphasize the need for standardized methodologies and long-term impact assessments to ensure that neuromarketing contributes constructively to public health communication.

Conclusion: The reviewed literature highlights the significance of these tools in enhancing the Overall, this article underscores the transformative potential of neuromarketing in the pharmaceutical domain while advocating for a balanced approach that safeguards consumer autonomy and promotes improved evidence-based marketing practices..

Keywords: Neuromarketing; Pharmaceutical; fMRI; EEG; Eye-tracking



Introduction

Neuromarketing become the cutting-edge approach to investigate the consumer behaviour via combining psychology, neuroscience as well as sophisticated analytics. It offers a more complex and empirically supported understanding of the factors that influence customer behaviour. Neuromarketing examines the hidden emotional and cognitive mechanisms which impact decisions as opposed to conventional marketing research techniques i.e., mostly rely on surveys and self-reported opinions that could be skewed or lacking. 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 intrigue to a useful toolkit used by international businesses in a variety of 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 of this field. In early 2000s, neuroscientists and marketers started working together to fill in the holes in conventional market research techniques that afforded the field of neuromarketing [2]. Biases like societal appeal, memory problems, or a lack of introspective insight to genuine intentions of people limit the useful declarative data about consumer preferences (that focus groups, surveys, and interviews). In order to overcome these constraints, neuromarketing measures neurological and physiological reactions that are indicative of unconscious processes. Neuromarketing has a wide range of uses including retail spaces, product designs and advertising campaigns [1,2]. Key objective of neuromarketing strategy includes decoding consumer decision-making, improving market efficacy, boosting customer engagement, optimizing product design or location and cutting down on marketing waste etc. are among the primary goals of neuromarketing techniques [3].

Neuromarketing Techniques and Tools

In order to create a comprehensive picture of consumer reactions, neuromarketing uses a broad range of scientific tools from behavioural science and cognitive neuroscience. One of the

most effective methods is still functional magnetic resonance imaging (fMRI), which analyzes changes in blood oxygenation to provide high spatial resolution pictures of brain activity. Brain areas linked to valuation (like the ventromedial prefrontal cortex), emotional processing (like the amygdala), reward (like the ventral striatum) and memory storage (like the hippocampus) can be found using fMRI investigations [4]. Nucleus accumbens activity has been demonstrated to forecast purchasing decisions and even market-level sales to provide marketers with predictive insights. In contrast, electroencephalography (EEG) offers better temporal resolution and can monitor real-time shifts in brainwave activity while participants watch commercials or use products. EEG can identify indicators of emotional sensitivity (e.g., asymmetry in frontal cortical activity), cognitive strain (e.g., parietal alpha suppression) as well as attention (e.g., frontal theta power) [5]. Eye-tracking technology is incredibly useful for optimizing websites, ad layouts and packaging since it can precisely identify consumers focus on visual aspects. Design changes can be informed by heat maps and gaze plots which can show the fact that important messages are observed or disregarded.

Heart rate variability (HRV) provides information on stress and engagement while galvanic skin response (GSR) gauges variations in the function of sweat glands as a stand-in for emotional arousal. Facial coding systems analyze micro-expressions to classify emotional states such as happiness, surprise, fear, or disgust, drawing on research pioneered by Paul Ekman. These methods are often combined in multimodal studies, enabling triangulation of findings and more robust interpretation. For example, an ad might generate high attention (eye-tracking, EEG) but low emotional engagement (GSR, facial coding), suggesting a need to increase affective resonance [4-6]. Advanced neuromarketing studies often incorporate behavioral outcomes (e.g., click-through rates, purchase data) to validate the predictive value of neural and biometric measures. Various technological advancements are deliberated below.

Neuromarketing in various sectors

Neuromarketing in the Retail Sector

The retail sector's adoption of neuromarketing is driven by its relentless pursuit of competitive advantage in an environment where consumer attention is fragmented and switching costs are low. Retailers seek to optimize every touchpoint of the customer journey, from window displays to checkout counters, to maximize conversion rates and basket sizes. Eye-tracking studies in retail settings have revealed that product placement on shelves, especially at eye level significantly boosts visibility and sales. Neuromarketing research has also demonstrated the impact of color schemes, signage and store layouts on navigational flow and dwell time [6]. For example, warm lighting and curved pathways can create feelings of comfort and encourage leisurely browsing, while bright lighting and straight aisles promote efficiency. Studies on neuromarketing have focused a lot of emphasis on ambient elements which are frequently disregarded in conventional marketing. According to research on scent marketing, pleasant as well as complementary scents can boost in-store time and even the perception of product quality. The tempo of background music affects how quickly people buy; slower music lengthens the duration of a purchase and increases overall expenditure. The utilization of these atmospheric components as strategic marketing levers is supported by GSR and HRV tests which verify that they produce quantifiable emotional and physiological reactions. Additionally, Eye-tracking along with facial coding are used to optimize online shopping interfaces which results in clear, captivating layouts to reduce friction and preserve pleasant emotional states. Neuromarketing provides a more scientific foundation to increase the customer experience and boost sales by firmly establishing retail design choices in empirical data on customer opinion and sentiment [7].

Neuromarketing in the Food and Beverage Industry

Emotional as well as sensory appeal are particularly important to the food and beverage sector. The potent influence of subconscious cues to influence customer preferences for packaging, brands and even flavour impressions has been made clear by neuromarketing. For example, Branding can literally alter the manner

in which brain interprets flavour, according to neuroimaging research. As opposed to blind tasting, Coca-Cola branding enhanced activity in reward and memory-related brain regions in a recognized experiment. It indicated that brand associations significantly influence sensory experience. Studies using face coding and EEG also showed the manner in which packaging design creates enjoyment and anticipation before consumption even began. One important application area is packaging optimization [7]. Eye-tracking determines whether design features, nutritional data and brand icons draw interest in competitive shelf environments. By measuring emotional reactions to various designs, facial coding and GSR make sure packaging reflects the intended brand positioning which may include natural ingredients and premium quality. To make sure they arouse appetite and desire without going against ethical guidelines when targeting vulnerable groups like children, food industry advertising efforts are also thoroughly pre-tested using neuromarketing techniques. The difficulty of preserving an identical corporate image of brand while connecting with a variety of markets is addressed by cross-cultural neuromarketing research which assists multinational brands in tailoring campaigns to local emotional triggers and cultural conventions. When used in conjunction with biometric monitoring, taste assessments can help product developers to uncover complex emotional reactions that conventional hedonic rating scales might overlook. Brands can optimize formulations to enhance acceptance and pleasure by monitoring emotional excitement in real time [7, 8].

Neuromarketing in Financial Services

Although the financial services industry is frequently seen as analytical and logical, a wealth of behavioural economics research has demonstrated that heuristics, prejudice and emotion play a significant role to determine the way people save, invest and borrow money. A method for rigorously studying these drivers is neuromarketing. Building trust is one of the important applications. Customers frequently have doubts or concerns regarding financial organizations. Advertising content can be tested for its capacity to activate reward and trust-related brain areas through

neuromarketing research employing EEG and fMRI. Particularly crucial in regulated settings, eye-tracking and face coding make ensure that disclosures and promises are observed and processed. Digital interface design is another field. Fintech apps and online banking must strike a balance between ease of access and privacy cues that ironically cause worry. Neuromarketing can be used to determine if communications successfully elicit this bias without going too far in evoking fear. Financial services companies can improve client comprehension and decision-making while cultivating trust and loyalty by establishing communication on factual knowledge of cognitive as well as emotional reactions [9].

Neuromarketing in Entertainment and Media

To capture and maintain audience attention, emotional involvement and to generate unforgettable experiences, media and entertainment sectors are mainly concerned. These sectors may assess and improve content with never-before-seen precision courtesy of potent capabilities of neuromarketing. Pre-testing trailers, ads and even full-length productions with EEG and facial coding is one important application. While facial coding categorizes emotional reactions like delight, surprise and terror, EEG may pinpoint specific times when viewers are most attentive or when their focus is declining. Editors can modify narrative arcs, tempo or visual focus to enhance emotional effect on the basis of this feedback. For example, experiment with different cuts to figure out which one best maintains suspense and excitement in a suspense movie trailer. In order to understand the reason behind universally relatability of some characters or stories, fMRI research has also been utilized to investigate the role of narrative components to stimulate reward pathways or social cognition connections in the brain. In order to improve user interfaces and make sure that recommendation algorithms and content thumbnails grab interest of users, streaming services incorporate insights from neuromarketing. Eye-tracking studies have shown which layouts and visuals best reduce choice overload and encourage sustained viewing sessions. Furthermore, neuromarketing is informing the design of transmedia

campaigns that span TV, film, social media, and gaming [6,10].

Neuromarketing in the Pharmaceutical Sector: An Overview

Among all industries adopting neuromarketing, the pharmaceutical sector stands out for its unique blend of complexity, importance, and ethical stakes. Unlike fast-moving consumer goods, pharmaceutical products address life-and-death health issues, involve multiple decision-makers (patients, physicians, caregivers), and are subject to tight regulatory oversight. Marketing in the pharmaceutical space must navigate a highly informed audience of healthcare professionals, an often-anxious and vulnerable patient population, and strict rules on claims, disclosures, and targeting [2,7]. By using neuroscience-informed methods, pharmaceutical companies can better understand how patients process risk-benefit information, what emotional barriers 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, allowing for clearer, more effective sales and educational materials. Pharmaceutical companies must ensure that neuromarketing-based strategies support, rather than undermine, informed consent and patient autonomy. They must also comply with strict advertising standards that forbid misleading claims and require balanced risk communication. As a result, neuromarketing in pharma demands a highly disciplined, transparent, and ethically aware approach [11].

The Patient Perspective: Emotions and Adherence

One of the most difficult problems in healthcare is still medication adherence. Research continuously demonstrates that a significant number of people do not take their prescription drugs as directed which results in worse health outcomes, longer hospital stays and greater overall healthcare expenses. Rational appeals such as informing patients for clinical benefits or giving them dosage instructions, have historically been the focus of adherence programs. However, these methods frequently overlook the significant emotional as well as cognitive elements that influence adherence behaviour. One method to identify and

address these unconscious drivers is neuromarketing. For example, fear of side effects may not be purely rational but deeply emotional, tied to anxiety circuits in the brain that can be measured through EEG or fMRI. Distrust of pharmaceutical companies may stem from implicit biases activated by branding elements, which can be identified through facial coding or GSR. By applying eye-tracking, companies can ensure patient education materials highlight the most critical information. EEG can test whether videos explaining medication regimens actually hold attention and reduce anxiety. Packaging design can be optimized to convey safety, ease of use, and clarity, reducing both cognitive and emotional barriers to adherence. Ultimately, neuromarketing offers a way to make adherence interventions more patient-centered, recognizing that successful behavior change requires addressing not just knowledge gaps but also emotional needs and cognitive biases [10-12].

Physician Targeting and Communication

Physicians occupy a central role in pharmaceutical decision-making, yet they too are subject to cognitive biases, emotional responses, and information overload. Neuromarketing offers pharmaceutical marketers a more scientific way to design communications that respect needs of physicians while improving clarity and persuasive impact. EEG can evaluate cognitive workload to make sure presentations are not excessively complicated or confusing while eye-tracking can show that particular section of a clinical investigation is important or are ignored. Reps can modify their tone and approach by using facial coding to identify subtle emotional responses to assertions [6]. For example, Eye-tracking information may be utilized to develop booth layouts that optimize accessibility and attention. To make sure they convey complicated information without confusing viewers, interactive displays might be evaluated for their emotional impact and cognitive stress. Programs for continuing medical education (CME) offer additional opportunities. Designing CME materials that sustain interest, lessen cognitive fatigue along with improvement in long-term memory encoding can be aided by insights from

neuromarketing. Pharmaceutical businesses can enhance not only marketing results but also the sharing of important clinical knowledge by implementing scientifically verified physician communication tactics. To target physician, neuromarketing should strive for transparency, participation and trust-building rather than manipulation. This will also ensure that busy physicians catch information by which they can comprehend and assess for betterment of their patients [13].

Branding and Trust in Pharmaceuticals

Branding is essentially unique in the pharmaceutical sector than how it works in other consumer goods. Trust is a must for access to markets and patient consent, not only an advantage over rivals. Pharmaceutical products entail significant personal stakes, health hazards and frequently life-or-death choices, in contrast to soft beverages or clothing. Therefore, the emotional motivators of legitimacy, safety and trust are essential to effective marketing. Pharmaceutical companies can use advanced methods from neuromarketing to identify and enhance these drivers. For example, visual branding components like font, colour schemes and logos are not solely artistic decisions, they also subtly convey professionalism and security [6,7]. EEG and fMRI neuromarketing research have demonstrated that specific colours and design components consistently activate brain areas linked to trust including the medial prefrontal cortex. Whereas, facial coding can determine whether marketing imagery evokes affection, reassurance or scepticism while eye-tracking can verify whether safety warnings and company certifications are truly noticed. Neuromarketing may improve packaging design to convey premium quality, safety as well as simplicity of use in addition to visual identification. For instance, tamper-evident features can boost perceived safety while clear language and simple design can lessen cognitive burden. Iterative design changes are made possible by the use of biometric data including GSR and HRV which may determine the ability of packaging to cause pleasure or stress. Neuromarketing validation is also beneficial for brand message. EEG and facial coding can show whether or not recordings of patient testimonials elicit a true emotional response. In

the end, these insights enable pharmaceutical businesses to create emotionally compelling brands that adhere to the strictest ethical guidelines. Honesty, clarity and empathy are certain qualities that neuromarketing can assist to establish trust rather than manipulation [11,14].

Navigating Regulatory and Ethical Constraints

Pharmaceutical marketing is one of the most strictly regulated industries in the world. Regulations are in place to safeguard patients from false promises, provide informed consent and maintain the integrity of medical judgement. The application of neuromarketing in this setting presents potential as well as difficulties that call for ethical and methodical behaviour. Around the world, regulatory frameworks varied. The FDA in the United States stipulates that hazards be disclosed as clearly as benefits in order to maintain fair balance in DTC advertising. Pharmacies are not allowed to advertise directly to consumers in Europe while professional communications are expected. Neuromarketing discloses powerful tools for influencing subconscious triggers of trust, fear as well as desire. While these insights can improve clarity and empathy in health communication, they can also be misused to bypass rational evaluation or exploit vulnerabilities—such as by unduly amplifying fear of illness to boost sales. Responsible pharmaceutical marketers must establish internal guidelines to ensure that emotional appeals support, rather than undermine, informed patient choice. Data privacy is another critical area [15]. Neuromarketing studies often collect highly sensitive biometric and neurophysiological data. Informed consent is essential, with participants clearly understanding what data will be collected, how it will be stored, and how it will be used. Companies must comply with data protection laws like GDPR in Europe or HIPAA in the U.S. when research involves patient information. Industry associations have begun developing voluntary codes of conduct for ethical neuromarketing, promoting transparency, participant welfare, and responsible use of insights. Pharmaceutical firms can demonstrate leadership by adopting these standards, building trust not only with consumers but also

with regulators, healthcare providers, and society at large [15,16].

Literatures based on neuromarketing in various sectors of market including health sector

The rapid increase in mortality from socially dangerous diseases, the drug market monopolizing by the large pharmaceutical companies, as well as increasing of the supplying with the generic drugs of various groups, are forcing manufacturers to use new technological and marketing tools to attract potential consumers: doctors, pharmacists and patients to their pharmaceutical products. Neuromarketing methods can be widely used during innovative technologies enter the market and can be used in HTA [17]. The development of medical information technologies and communications entailed the formation of new areas of marketing, namely neuromarketing. Research on neuromarketing began by scientists in 1990. However, the term was firstly introduced in 2002. Neuromarketing is a commercial marketing communication using methods of neuropsychology and biology [18,19]. In neuromarketing, a number of consumer's reactions to the proposed product are used, the most common of which are: sensorimotor, cognitive and affective. So, sensorimotor reactions were firstly described in the theory of cognitive development of Piaget, which is based on the development and reactions of human intellect. The key points of the theory are the processes of assimilation and adaptation. Assimilation is the perception of new information and its comparison with new ideas, and adaptation is the receipt of information and its application with old ideas. Cognitive reactions are aimed at the process of cognition, understanding and comprehension, as well as the processing of information receiving [20]. Affective reactions as analytical categories define behavior associated with experience, feeling and emotions. That is, neuromarketing is aimed at studying how the nervous system and the brain react to various advertising techniques using medical methods and not only. Thus, in the process of new health technology assessment after research, it is advisable to apply neuromarketing methods to analyze patient responses [10,21]. It is necessary to take into account ethical standards, social and psychological aspects, as

well as an assessment of technology financing. That is, if the state or a large pharmaceutical corporation is interested in developing of a new health technology, it is necessary to justify the level of financing from the state budget and include the technology in the reimbursable list. An important criterion for the harmonious implementation of health technology is feedback, that is, feedback from patients who are not self-medicating, but who consciously use the medicines [21]. According to the Evaluate Pharma World Preview data, the medicines market will increase by an average of 6.5% every year and it is forecasted volume in 2022 will be 1.12 trillion dollars [22]. Thus, neuromarketing methods can be used not only to evaluate a new technology that is entering the market, but also to create the "correct" promotion of medicine advertising and to familiarize patients with effective and safe drugs [23]. It should be noted that the advertising of medicines in the countries of the world is strictly regulated. So, prescription medicines advertising is provided by law not in all countries. For example, a policy of tough advertising in Poland is currently underway. The U.S.A. Food and Drug Administration (FDA) has created a number of drug advertising requirements. According to established FDA requirements, advertisements for pharmaceutical products must not be false or misleading; it should reflect the risk, benefit and all the side effects that are described in the annotation when using the medicine [6,24]. With regard to medicine advertising in the European Union countries (EU), according to Directive 92/28 / EU, the advertising of prescription drugs and those containing narcotic or psychotropic substances is prohibited, that complies with the definitions of international conventions. It is also should be noted that in the EU advertising of medicines for the treatment of certain categories of diseases is prohibited, namely: tuberculosis, diabetes, cancer, sexually transmitted diseases, etc. and most of the medicines that are reimbursed by the government also. Therefore, when introducing medicines advertising using neuromarketing methods, there are a number of risks, not only for pharmaceutical holdings, but also for potential patients.

The influence of marketing techniques, in particular neuromarketing in medicines' advertising, has been described in many scientific papers. For instance, Orzan *et al.*, highlighted that neuromarketing methods affect the unconscious and conscious choice of the consumer [24]. Further, Morin had concluded that neuromarketing offers advanced methods for the direct study of human brain reactions without requiring the cognitive or conscious participation of an individual [25]. Żurawicki and their team had summarized data on the impact of advertising aimed at a wide audience [26]. The study by Wolbring *et al.*, had discussed the impact of marketing techniques using various technological interfaces on healthcare, as well as on consumers with limited capabilities [27]. Furthermore, Javor and their group drawn a relationship between neuromarketing and neurology and how it affects the pathophysiological requirements of people suffering from diseases that are significant to society (like Parkinson's disease) [28]. Fisher in collaboration with co-authors had described the contradictions regarding the involvement of neuromarketing in the practice of medical workers, scientists and other entities [29]. According to Kumar *et al.*, neuromarketing is a branch of psychiatry and can be considered as a study of human behavioral factors [30]. In the work of Nicolae, the significance and use of neuromarketing techniques in development of neuroscience, as well as in market research had been examined. The investigation of 67 neuromarketing businesses located across the globe that are NMSBA members served as the framework of study [31]. In another literature, Radu and co-workers had described the impact of marketing on consumer preferences in the pharmaceutical industry [32]. In a paper by Unguryan, the influence of neuromarketing methods on consumers is examined through observations in pharmacies in one of the largest industrial centers of Ukraine. It has been established the importance of upgradation of neuromarketing approaches in most pharmacies [33]. In next, Gromovik and Unguryan identified the possible advantages and disadvantages of the ethical nature of neuromarketing for pharmacy, as well as the influence of sensory marketing methods on

consumer choice [34]. Moreover, Malyi *et al.*, had revealed that the use of neuromarketing makes it possible to manipulate the minds of buyers and make rash purchases [35].

Neuromarketing approaches: Emerging strategy in marketing

A multi-dimensional framework showcasing a variety of neuromarketing methods and approaches utilized to carry out the behavioural study was offered, according to the data gathered through neuromarketing literature. These neuromarketing resources and techniques were compiled according to specific study contexts and unique criteria, like as capturing brain electrical and metabolic signals. Electrical activity in the brain can be recorded and measured using steady-state topography (SST) and transcranial magnetic stimulation (TMS), along with Electroencephalography (EEG), Magnetoencephalography (MEG), and Event-related potential (ERP). It has been discovered that additional methods including Positron Emission Tomography (PET), Functional Magnetic Resonance Imaging (fMRI), and Functional Transcranial Doppler Sonography (fTCS) can reveal details about the metabolic activities of brain [36]. Heart rate (ECG), facial recognition i.e., facial EMG, eye tracking, implicit association test (IAT) and galvanic skin response are several methods for recording and analyzing physiological biometric activity without the ability to record cerebral metabolic activity. The use of fMRI to capture and analyze

brain activity in reaction to marketing communication inputs has grown in consumer behavioural research that provides insights into the decision-making process [37]. However, other alternative techniques might be deployed based on the research objective and available resources. Figure 1 categorizes the various neuromarketing tools based on their ability to measure the metabolic and electrical activities of brain. The information generated from content analysis and the literature is synthesized into an integrated conceptual framework that delves into consumer behaviour based on neuromarketing. The framework is founded on the theory of reasoned action, depicting the interplay between consumers' purchase intentions and their real behaviour, elucidating the relationship between stimulus and response and with neuromarketing effect positioned at the centre of marketing activities. This model may potentially bridge the gap between the knowledge, attitude, and perception of a consumer by examining the effects of neuromarketing in specific circumstances [38]. This theoretical framework bridges the gap and identifies the importance of neuromarketing as an additional aspect which impacts the process of making decisions [39]. It complements the available knowledge domain of consumers which demonstrated the desire to buy and are emotionally, economically and psychologically compatible to the subsequent stage of buying a product.

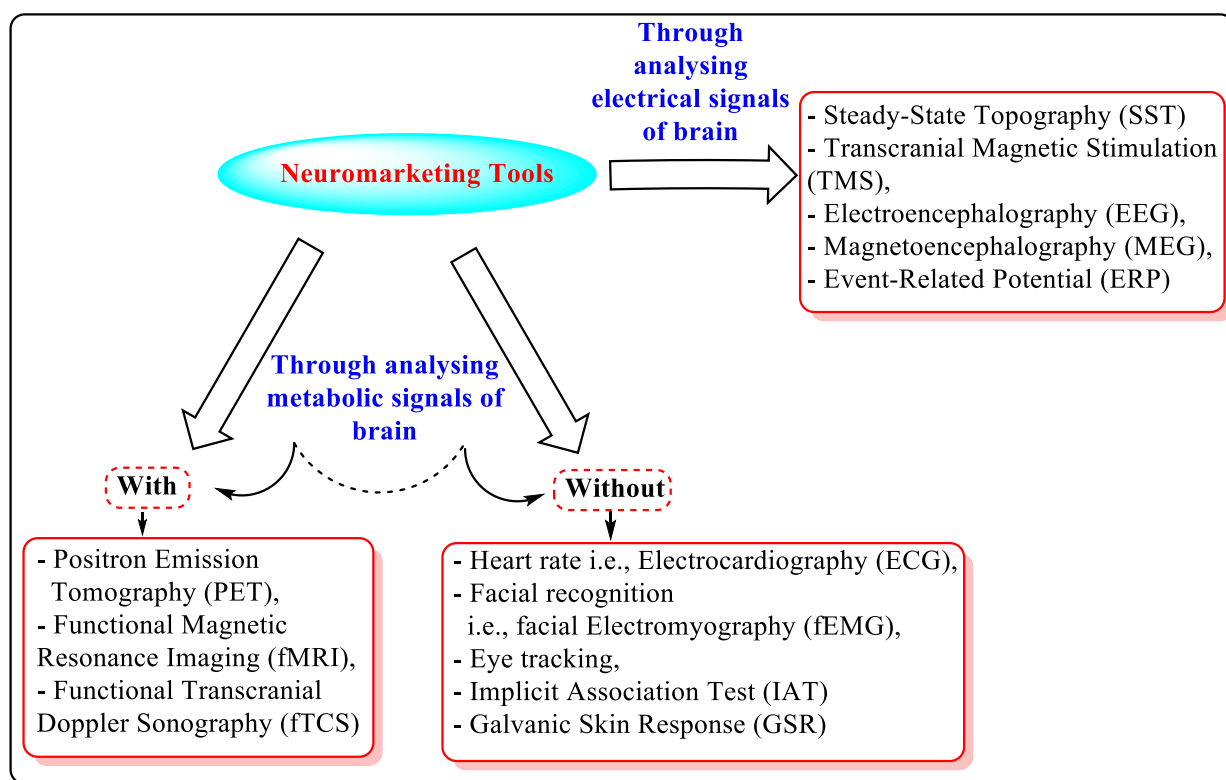


Figure 1. Various neuromarketing tools and techniques

The framework (as depicted in Figure 2) portrays the logical relationship between purchase intention as an antecedent and real buying behaviour as the outcome. The process behind the production of antecedents and outcomes, specifically decision-making and transformation of purchase intentions into actual buying behaviour is influenced by a number of variables. The expansion 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 consumers include

those that are concerned with the consumer and influence their decision-making, such as attitudes, perceptions, and emotions. 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 related to consumers have the potential to moderate consumer responses, whereas extrinsic factors related to the environment may have a direct impact on consumer behaviour that affects purchase outcomes.

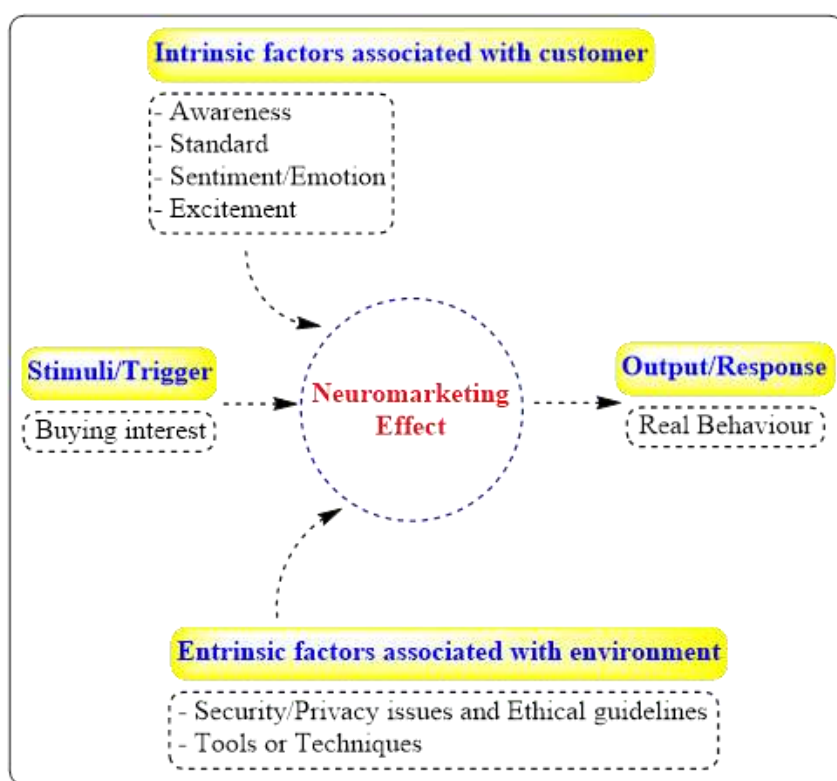


Figure 2. Theoretical framework of neuromarketing effect on response of consumer

Neuromarketing tools: Their advantages and limitations

The integration of neuromarketing approach with consumer behavioural domain facilitates strategic decision making across diverse areas, such as market segmentation, product development, and product packaging to pricing strategy [40]. Businesses could leverage market segmentation based on consumer preferences and choices, which consider biases in neurological characteristics, without any reference to psychographics or demographics. In addition to product development,

neuromarketing can contribute to brand development by providing valuable insights to improve brand promotional campaigns [41], reverberating through meticulous design considerations, from advertisement banners and hoardings to posters and media planning. This section presents an anthology of typical marketing studies based on the fundamental neuromarketing principles, which informs about the suitability of tool used to conduct research studies customized to specific user contexts (Table 1).

Table 1. Various neuroscientific tools used for specific user contexts

Entry	User context	Neuroscientific tool	Focus
1	Grocery items	EEG	Price [42]
2	Chocolate	fMRI	Product [43]
3	Advertisement	Eye Tracking	Product [44]
4	TV ads	EEG	Product [45]
5	Consumer products	EEG	Price [46]
6	Food	fMRI	Product [47]
7	Crackers	Eye Tracking	Product [48]
8	Soft drinks and water-filled bottles	fMRI	Product [49]
9	Snacks	Eye Tracking	Product [50]



Marketers and researchers have highlighted various neuromarketing techniques that serve as functional strategies within different areas of marketing, considering the advantages and limitations of the tools. To improve customer insights, strategies are developed by combining traditional methodologies with neuroimaging functions or neuroscientific tools with sensory marketing strategies [51]. Neuroimaging

techniques function as per the recorded physiological metabolic activity of a localized area of action in the body, such as the brain, eye, or skin, thereby acting as a good indicator of consumers' choices and preferences. Table 2 highlights the advantages, benefits, localized area of action, and limitations of neuromarketing tools.

Table 2. Several advantages, benefits, localized area of action, and limitations of neuromarketing techniques

Neuromarketing tool	Benefits	Location of effect	Limitations
Electroencephalography (EEG) [52]	These methods can be utilized for evaluating 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) [53]	- Address activities of little regions - Evaluate and distinguish adjacent signals - Examination of the entire brain	Specific brain region oxygen use	- Physically Challenging - Costly
Eye Tracking [54]	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) [55]	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) [56]	Easy and thoroughly verified	- Heart rate - Pupil dilation	- The ability to differentiate between positive and negative arousal is lacking
Facial electromyography (fEMG) [57]	- Continuous observation of subconscious emotional reactions to continuous sensory input - Software for automatically encoding pictures of faces	Facial effective coding	- It affixes electrodes to the face directly

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, as outlined by Renvoisé and Morin, which divides the brain into: 1) Neocortex (Thinking Brain): Responsible for logical analysis and rational decision-making; 2) Limbic System (Emotional Brain): Influences preferences subconsciously through emotions and feelings;

3) Reptilian Brain (Old Brain): Governs survival instincts and basic functions, playing a key role in evaluating risks and needs [24]. 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. Emotional advertising has been shown to outperform rational advertising, particularly in memory retention. Techniques

such as fMRI and EEG analyses reveal brain regions involved in decision-making, like the striatum and ventromedial prefrontal cortex, providing deeper insights for companies to enhance consumer engagement. In the context of social media, neuromarketing shows that ads with minimal editorial content and featuring celebrities gain more attention.

Neuromarketing is becoming increasingly sophisticated with technology, using neural networks and neuroscience-based metrics to predict ad effectiveness [52,53,58]. This approach helps companies understand consumer behaviour and create stronger emotional connections through targeted advertising strategies (as depicted in Figure 3).

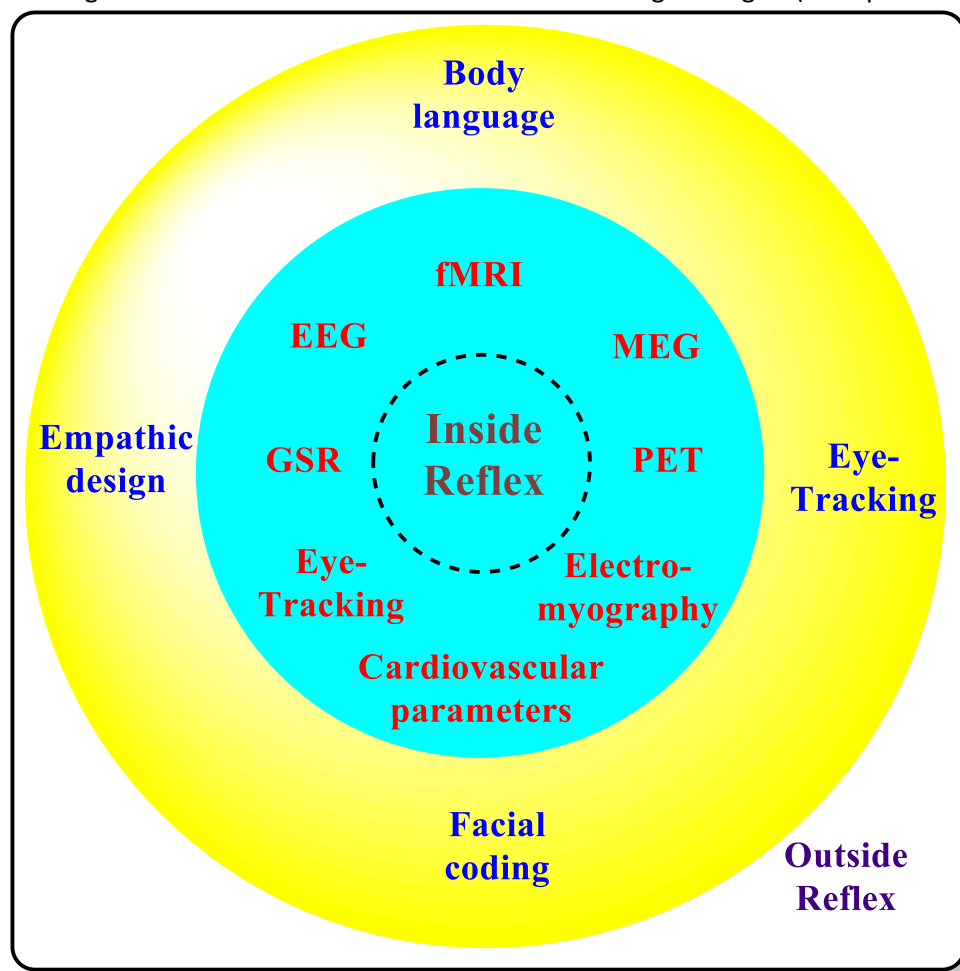


Figure 3. Inside and outside reflex neuromarketing techniques

Role of Neuromarketing in Health Services including Pharmaceutical Field

Pharmaceutical companies currently have more obstacles to overcome throughout their efforts to market and sell their goods. Pharmaceutical products that are novel and inventive are introduced to the market. The firm is profitable due to which competition is fierce. Every business aims to stand out from the competition and draw in customers with the advantages of their goods. Advertising is crucial in this situation. In recent years, businesses have been able to gain greater insights into their customers by utilizing a new science known as neuromarketing. In order to better understand the manner in which our central nervous system

responds to marketing stimulation, neuromarketing employs certain medical procedures [59]. The marketing expert can uncover the expectations, feelings and emotions by employing neuromarketing strategies. Neuroimaging and other neurological techniques have become common research tools in both the economic and social sciences. Specifically, modern economics has created neuromanagement, neurofinance, neuromarketing, and neuroaccounting. These new fields use practical factors in addition to their more significant scholarly goals [60]. However, not much information is available regarding 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, galvanic skin reaction, EEG and fMRI. They are chosen based on their cost and possible outcomes. The brain is the most fascinating subject for study of all. The most intricate organ in the human body is the brain. When researching participants with varying ages or educational levels, marketing specialists collect distinct image due to synapses alter with experience and learning. After testing these methods for years, the neuromarketers discovered that while we have three brains to aid in our decision-making, we only have one decision-maker [37,52-54]. Neuromarketing research employs several methodologies to examine health concerns more precisely. In this regard, Functional magnetic resonance imaging or fMRI, is a medical technique that measures blood flow oxygen levels to gauge the activity of the brain. Each part of the brain needs more oxygen in the active state [61]. Further, Electroencephalography or EEG, records and monitors the way the brain produces electrical activity [62]. Furthermore, Steady State Topography or SST, records and analyses brain activity. SST can be used in neuromarketing experiments on television advertisements because of its great temporal resolution [63]. Moreover, MEG (Magnetoencephalography) utilizes magnetic field to provide data on activity of brain. Unlike functional techniques like fMRI, it measures brain activity directly. Its spatial and temporal resolution is significant [64]. The number of breaths typically taken in a minute is known as the respiratory rate. Heart rate is the average number of heartbeats in a minute while a pupilometer is a device employed to assess the dilation or relaxation of pupil of participants when exposed to a visual trigger [65]. In addition, skin conductance, also known as galvanic skin response, quantifies records the electrical events of the skin which vary with the amount of moisture present [66]. Also, eye tracking technique which monitors attention the eyes while the psychophysiological stress reactions that occur in human speech are captured by voice analysis [67].

Applications of Neuromarketing in Pharmaceuticals, Ethical considerations and Future outlook

Neuromarketing measures brain activity, physiological responses and unconscious activities directly. Also, client confidence, ethics and their regulation are particularly important in pharma industry, neuromarketing has become a contentious and promising method to study the decision-making process in patients and healthcare professionals [68]. Neuromarketing looks at neural and emotional reactions to marketing stimuli with the help of methods like eye-tracking, electroencephalography, functional magnetic resonance imaging, facial coding and galvanic skin response, in contrast to existing conventional marketing research that depends on surveys groups [36,69]. Pharmaceutical businesses may leverage this for their advantage by optimizing branding, advertising and package design in order to appeal to the subconscious factors that influence trust and choice. Pharmaceutical firms frequently face competition from identical products in highly competitive markets. By testing branding components like as logos, colours, package designs and message at a subconscious level, neuromarketing enables businesses to determine the triggers that elicit feelings of efficacy, safety and trust [2,11,70]. For instance, consumers may 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 US. Without going against moral principles, neuromarketing can evaluate memory encoding along with emotional involvement during ad exposure to improve clarity and effect of messages. It is possible to maximize subtle aspects like tempo, tone of voice and music to guarantee improved recall and favourable brand associations [71]. Medication non-adherence is still a major problem in the medical field. By utilizing knowledge of anxiety and relief reactions, neuromarketing can be applied to create more emotionally compelling and convincing patient education materials. Adherence rates can be raised by packaging and directions that lessen cognitive burden and foster a stronger emotional bond [11,72].

In spite of 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 take advantage of these weaknesses and put sales at priority in front of health of people. Because neurological and physiological data are very confidential, there are privacy and safety issues. Small sample sizes and excessive interpretation of brain imaging data are common problems in neuromarketing research. To ensure that results are repeatable and significant, future studies must use strong experimental procedures and statistical rigor. 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, observational and sales data. Different cultures and age groups have different emotional reactions to marketing stimuli. The generalizability of neuromarketing findings across a range of patient demographics has to be studied.

Conclusions

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 as well as physiological responses, pharmaceutical businesses can determine whether aspects of their branding, messaging or packaging designs implicitly inspire safety, efficacy and trust of consumer. Enhancing patient education resources, encouraging drug adherence through emotionally charged interactions and improving direct-to-consumer advertising within controlled parameters can all result from neuromarketing. Furthermore, neuromarketing provides insightful information for healthcare professionals to assist the optimization of intricate scientific presentations as well as marketing collateral to increase trust and clarity without being manipulative. But

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 putting patient welfare first, this raises questions about inappropriate influence or exploitation. Because brain and physiological data are extremely personal, data privacy becomes especially crucial. Pharmaceutical businesses are required to gain 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 behavioural and self-report measures to increase methodological rigor. Although industry, regulators and researchers must work together to build ethical frameworks specific to pharmaceutical marketing, cross-cultural investigations are required to ensure the universality of findings. Finally, potential of neuromarketing to enhance health outcomes can only be fulfilled if it is used sensibly *via* utilizing the latest research to empower and educate both patients and healthcare professionals.

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