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ROBUSTNESS OF ELECTROENCEPHALOGRAPHY IN MARKETING RESEARCH: A META-ANALYSIS

ROBUSTEZ DA ELETROENCEFALOGRAFIA EM PESQUISA DE MARKETING: UMA META-ANÁLISE

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Abstract

This study assesses whether EEG findings in consumer research provide sufficiently consistent cumulative evidence to inform marketing research and decision-making. Using a PRISMA-guided meta-analysis of 18 experimental studies, we estimated the overall effect of EEG markers and examined heterogeneity, moderators, and publication bias under a random-effects model. Results indicate a positive and significant overall effect (d = 0.63), with moderate heterogeneity and stable estimates after sensitivity analyses. The findings suggest that EEG offers complementary value to marketing research by capturing implicit cognitive and affective responses, particularly in pretests involving advertising, brands, products, and price cues.

Keywords: Consumer neuroscience. EEG. Consumer decisions. Neuromarketing. Meta-analysis.

Resumo

Este estudo avalia se os achados com EEG na pesquisa do consumidor fornecem evidências cumulativas suficientemente consistentes para informar a pesquisa e a tomada de decisão em marketing. Por meio de uma meta-análise orientada pelo protocolo PRISMA de 18 estudos experimentais, estimamos o efeito global dos marcadores de EEG e examinamos heterogeneidade, moderadores e viés de publicação sob um modelo de efeitos aleatórios. Os resultados indicam um efeito global positivo e significativo (d = 0,63), com heterogeneidade moderada e estimativas estáveis após análises de sensibilidade. Os achados sugerem que o EEG oferece valor complementar à pesquisa em marketing ao captar respostas cognitivas e afetivas implícitas, particularmente em pré-testes envolvendo publicidade, marcas, produtos e preços.

Palavras-chave: Neurociência do consumidor. EEG. Decisões de consumo. Neuromarketing. Meta-análise.

Introduction

In recent years, there has been a growing and systematic integration of neuroscience into core areas of management and business, reflecting a broader movement toward incorporating biological and cognitive approaches into the understanding of economic and organizational behavior (Pereira et al., 2024). Within this context, neuromarketing has emerged as an interdisciplinary field that integrates contributions from behavioral psychology, economics, technology, and neuroscience to investigate the cognitive, emotional, and physiological determinants of consumer decision-making (Pereira et al., 2024; Fugate, 2007; Vieira et al., 2020; Lim, 2018).

More specifically, neuromarketing is situated at the intersection of neuroscience and marketing and focuses on examining how the nervous system responds to market-related stimuli, such as advertisements, products, and brands, through the use of neuroimaging techniques, including electroencephalography (EEG), functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS), and magnetoencephalography, often integrated with complementary methods such as eye tracking and biometric measures (Kalaganis et al., 2025; Panteli et al., 2025).

Despite these methodological advances, empirical evidence indicates that between 70% and 85% of new products fail within the first months after market launch, largely due to the limited ability of traditional declarative methods to anticipate actual consumer behavior in real market settings (Vecchiato et al., 2014; Mengual-Recuerda et al., 2020). This limitation stems from inherent constraints of self-report–based approaches, which are systematically affected by social desirability biases, normative pressures, and individuals' difficulty in accessing or verbalizing emotional and cognitive processes that predominantly operate outside conscious awareness at the moment of decision-making (Touchette & Lee, 2017; Hakim et al., 2021; Zito et al., 2021).

As a consequence, declarative evaluations tend to capture rationalized and socially acceptable judgments, while failing to access the implicit mechanisms that effectively guide choice and consumption behavior. Within this context, neuromarketing emerges as a relevant methodological alternative by enabling the direct measurement of psychophysiological responses and access to implicit affective and cognitive processes that escape traditional approaches (Genevsky & Boksem, 2024).

Evidence suggests that neuroscientific techniques provide more objective indicators of consumer behavior because they do not rely exclusively on conscious reports or on participants' willingness to reveal their true preferences, thereby mitigating biases associated with self-reflection and strategic responding (Wang et al., 2024; Gountas et al., 2019; Izadi et al., 2022). Among these techniques, electroencephalography (EEG) has become the most widely used tool in consumer behavior research due to its high temporal resolution, economic feasibility, and increasing portability (Ishtiaque et al., 2025; Shang et al., 2024).

Given that cognitive and emotional processes relevant to decision-making occur on a millisecond timescale, EEG offers substantial advantages in capturing the temporal dynamics of attention, evaluation, and motivation in response to marketing stimuli (Alvino et al., 2021; Zeng et al., 2021; Raiesdana & Mousakhani, 2022). Accordingly, EEG is widely recognized as a central component of functional brain activity research applied to the study of consumer behavior (Adalarasu et al., 2025).

From a marketing research perspective, however, the key issue is not merely whether EEG can detect neural responses to market stimuli, but whether the accumulated evidence is sufficiently consistent to enhance inference in consumer research and support more informed decision-making. Although EEG has been increasingly applied in studies of advertising, branding, product evaluation, and pricing, its practical value for marketing research remains difficult to determine, as findings are dispersed across diverse experimental paradigms, neural metrics, and analytical strategies. In this sense, establishing the overall magnitude, robustness, and boundary conditions of EEG-based effects becomes essential for

clarifying when this technique can provide reliable complementary insight beyond traditional declarative methods.

Against this backdrop, a central question in the contemporary literature concerns the extent to which EEG-derived neurophysiological markers can consistently and generalizably discriminate psychological states associated with consumer preference and purchase intention. The importance of this issue is reinforced by the rapid expansion of scientific output over the past decade, marked by a substantial increase in studies investigating the neural correlates of consumption-related decision-making (Alsharif & Isa, 2025; Wang et al., 2024). In this context, assessing the effectiveness of markers such as frontal alpha asymmetry (FAA) and event-related potentials (ERPs) extends beyond purely academic interest and becomes strategically relevant for the development of more effective marketing practices, including advertising design, branding, and pricing decisions (Alsharif & Isa, 2025; Khondakar et al., 2024).

Recent literature has organized the application of EEG in marketing into major stimulus clusters, notably advertising, product, price, and brand (Alsharif & Isa, 2025; Wang et al., 2024). In the advertising domain, which accounts for the largest proportion of studies (approximately 49%), research has focused on advertising effectiveness, message content, and the impact of celebrity versus non-celebrity endorsements. In the product and price clusters, studies examine how visual, tactile, and auditory attributes, as well as perceptions of value and pricing strategies, modulate cortical activity. From a methodological perspective, these investigations primarily explore features in the frequency domain, such as spectral power in the alpha and theta bands, and in the time domain through ERP components such as N200, P300, and the late positive potential (LPP), seeking to relate neural patterns to affective and cognitive processes relevant to consumption (Byrne et al., 2022; Khondakar et al., 2024).

Despite the substantial volume of empirical studies and recent systematic reviews (Alsharif & Isa, 2025; Byrne et al., 2022; Khondakar et al., 2024; Wang et al., 2024), the literature remains characterized by considerable variability in findings. Systematic reviews, such as Byrne et al. (2022), explicitly highlight the presence of "limited consistency" and "mixed results." For example, although frontal alpha asymmetry is theoretically established as a marker of approach motivation, its association with preference measures varies considerably across studies. Similarly, components such as the P200 yield contradictory findings, being associated with both positive and negative evaluations depending on the experimental paradigm adopted. This heterogeneity is further exacerbated by significant methodological differences, including the use of clinical versus portable equipment, variations in preprocessing pipelines, and the diversity of stimuli employed, such as dynamic videos and static images (Alsharif & Isa, 2025; Khondakar et al., 2024).

In light of this scenario, existing systematic and bibliometric reviews have played an important role in mapping the evolution of the field and describing the main experimental designs employed. However, these approaches remain limited by their descriptive nature, as they do not statistically quantify the magnitude of the global effect associated with EEG-derived neural markers. Consequently, a critical gap persists for a quantitative synthesis capable of assessing the strength and consistency of this evidence.

Unlike narrative or bibliometric reviews that focus on identifying trends (Khondakar et al., 2024; Wang et al., 2024), the present meta-analysis aims to quantitatively synthesize the available empirical findings in order to clarify the variability observed in the literature. Specifically, it seeks to estimate the magnitude of the effect associated with markers such as FAA and LPP in discriminating psychological processes related to preference and purchase intention, while accounting for methodological and contextual moderators. This approach enables a shift from qualitative descriptions of "mixed results" toward more robust statistical inferences regarding the validity of EEG in the study of consumer behavior (Byrne et al., 2022).

Conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and grounded in a rigorous methodological assessment of the included studies, this quantitative synthesis aims to contribute to the theoretical advancement of neuromarketing while simultaneously providing a more solid empirical basis for the interpretation and application of neurophysiological markers in consumption contexts. To ensure scientific rigor and inferential validity, the study adopts the methodological protocols for marketing meta-analyses proposed by Paul and Barari (2022), encompassing all stages from research question formulation to sensitivity analyses and publication bias assessment.

Method

This study was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, as the recommendations outlined in the PRISMA checklist (27 items) are widely adopted in systematic reviews and are associated with more comprehensive and methodologically robust syntheses (Page et al., 2021). Accordingly, PRISMA guided the selection procedures and analytical processes through explicit inclusion and exclusion criteria applied across all stages of the review (Page et al., 2021).

In addition, the study protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD420251111988). At the time of registration, no equivalent protocols with comparable scope and methodological design were identified, underscoring the originality and relevance of the present study.

Beyond adherence to PRISMA for transparent reporting, the conduct of this meta-analysis strictly followed the TCCM framework (Theory, Context, Characteristics, Methodology) and the data analysis procedures recommended by Paul and Barari (2022). In line with these guidelines, the study implemented: (1) a rigorous screening process based on explicit inclusion criteria; (2) diagnostic analyses to detect influential outliers; (3) the application of a random-effects model estimated via restricted maximum likelihood (REML), appropriate for generalization in business research; and (4) robust publication bias tests, including Rosenthal's Fail-safe N and the Trim-and-Fill procedure, to ensure the validity and stability of the conclusions, as detailed in the subsequent sections.

Scope and Selection Criteria

The initial search and export of bibliographic records were conducted on July 4, 2025. The database selection strategy prioritized multidisciplinarity and relevance to the field of management, resulting in the inclusion of the following sources: Web of Science – Main Collection (Clarivate Analytics), Scopus (Elsevier), and Emerald Journals.

The deliberate choice of these databases, rather than strictly biomedical repositories (e.g., PubMed) or psychology-focused databases (e.g., PsycINFO), is grounded in the specific objective of this review: to examine the application of neurophysiological methods to marketing-related problems, rather than to clinical conditions or basic neural processes detached from consumption contexts. Web of Science and Scopus provide the most comprehensive coverage of high-impact journals at the intersection of applied social sciences and neuroscience, including seminal outlets in consumer psychology and neuroscience, while Emerald ensures the inclusion of literature specific to strategic management. This triangulation strategy ensures the retrieval of foundational consumer neuroscience research without diluting the sample with clinical studies outside the scope of consumer behavior.

Eligibility Criteria

Inclusion and exclusion criteria were defined to ensure thematic homogeneity, methodological quality, and statistical feasibility of the review. Eligible studies met the following requirements: (a) Language: published in English, Spanish, or Portuguese, in order to capture both the dominant global literature

and specific contributions from Ibero-American research; (b) Time frame: published between 2005 and 2025, a period corresponding to the consolidation of neuromarketing as an academic field; (c) Study design: exclusively empirical or experimental studies employing electroencephalography (EEG), including spectral analyses and event-related potentials (ERPs), to monitor neural activity; (d) Context: investigations focused on cognitive (e.g., attention, memory, decision-making) and emotional processes in direct response to marketing stimuli or consumption environments; (e) Availability of quantitative data: studies reporting complete inferential statistics (e.g., means, standard deviations, sample sizes, or exact t and F values) that allowed for the calculation or conversion of effect sizes.

Accordingly, theoretical papers, reviews (systematic or narrative), conference proceedings, books, editorials, and non-academic sources (grey literature) were excluded, as were clinical studies focused on neurological pathologies without associated marketing variables. In addition, to ensure the feasibility of the meta-analysis, studies with incomplete data were excluded, including those reporting only descriptive statistics without corresponding hypothesis tests or those providing p-values without the associated test statistics.

Methodological Quality Assessment and Risk of Bias

To ensure the robustness of the inferences drawn in this review, the methodological quality of the 20 included studies was assessed using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (Barker et al., 2024). The application of this tool was not intended to exclude investigations with small sample sizes or the absence of formal sample size calculations, as such characteristics are prevalent and often inherent to the complexity of data collection in consumer neuroscience. Instead, the assessment prioritized the integrity and completeness of the statistical data required for quantitative synthesis.

Unlike prior qualitative reviews, the focus was placed on the ability of studies to provide evidence convertible into effect sizes, requiring rigor with respect to the following quantitative criteria: (i) complete reporting of inferential statistics (exact t or F values, or means and standard deviations), rather than the isolated presentation of significance levels (p-values); (ii) availability of dispersion measures (variance or standard error) essential for inverse-variance weighting in the meta-analytic model; and (iii) precise specification of sample size (N) for each experimental condition or group. This approach ensured that all included articles provided a solid numerical basis for the calculation of Cohen's d, regardless of individual limitations in statistical power, which were systematically mapped and critically discussed in Section 4.

Data Analysis Procedures

The quantitative analysis was conducted using the R statistical environment, employing the metafor package. For effect synthesis, a random-effects model estimated via restricted maximum likelihood (REML) was adopted, as it is considered more appropriate for generalizing results in marketing research given the expected variability across studies. Heterogeneity among effect sizes was assessed using the I^2 statistic, while potential publication bias was examined using Rosenthal's Fail-safe N and the Trim-and-Fill procedure.

To ensure the robustness and integrity of the estimates, a sensitivity diagnostic analysis based on Cook's distance (D_i) was performed. Studies exerting disproportionate influence on the overall effect estimate (D_i > 4/n) were identified and treated as statistical outliers exclusively within the context of sensitivity analyses.

Effect Size Extraction and Calculation Procedures

To ensure comparability across studies and preserve the independence of observations, a single standardized effect size was extracted for each independent sample. Because EEG studies frequently

report multiple ERP components, frequency bands, electrode sites, and experimental contrasts, a pre-defined hierarchical decision protocol was adopted to guide effect size selection.

First, we identified the statistical contrast that most directly addressed the research question of this meta-analysis. Second, when multiple neurophysiological metrics were reported, priority was given to the outcome explicitly defined by the original authors as the primary measure. In the absence of such indication, the metric with the closest theoretical correspondence to the dominant psychological process under investigation was selected according to the *a priori* coding framework adopted in this review. Third, when multiple electrodes or recording sites were reported for the same component or frequency band, we prioritized aggregate estimates based on Regions of Interest (ROI) or, when only one summary test was available for the focal contrast, that summary statistic. This procedure avoided the inclusion of correlated effects derived from the same participant pool.

Effect sizes were calculated primarily from reported means and standard deviations. When descriptive statistics were unavailable, standardized effects were derived from inferential statistics reported in the original studies. Conversion procedures were defined according to study design, distinguishing between independent-group comparisons and repeated-measures designs, so that all included estimates could be expressed on a comparable standardized metric. At no stage were effect sizes selected on the basis of statistical significance or effect magnitude.

Search Strategy and Study Selection

To identify relevant records, we first examined the existing literature to determine the primary keywords commonly used to retrieve studies on the topic. In addition, the selected terms were validated through a pilot search conducted to test the effectiveness of the search strategy in retrieving relevant studies.

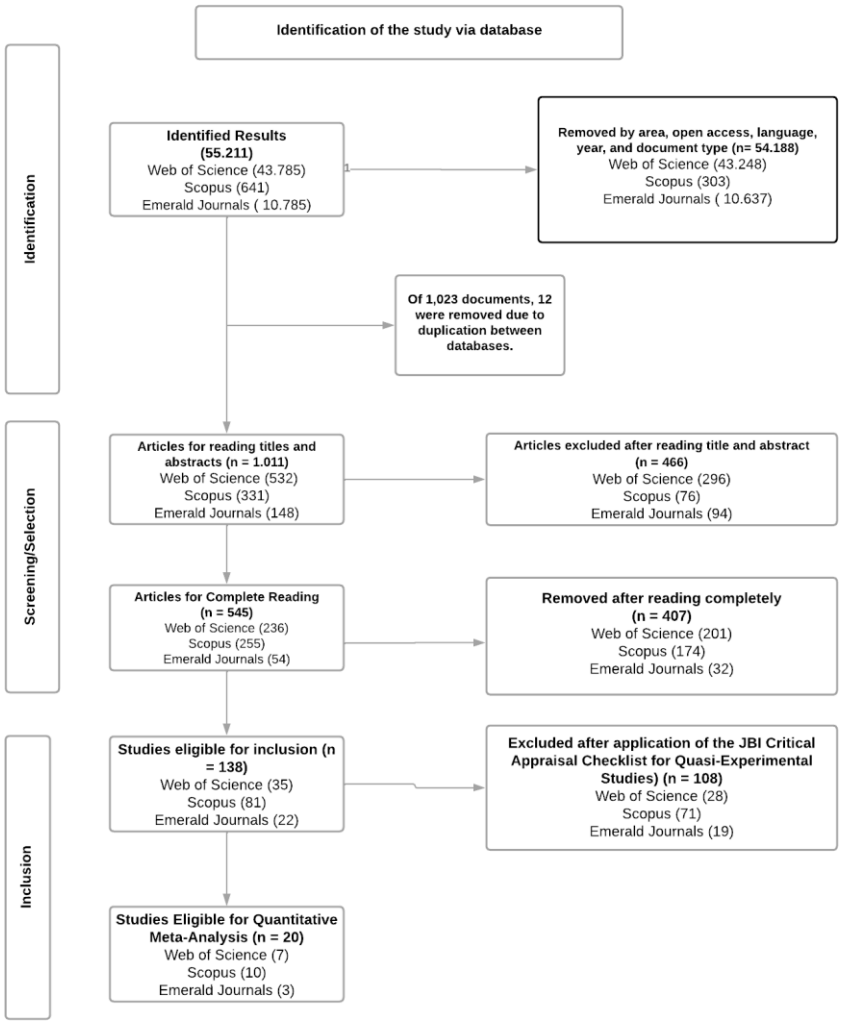
Accordingly, the search terms combined were: neuromarketing, consumer neuroscience, electroencephalography, EEG, event-related potentials, and ERP. Searches were performed across title, abstract, and keyword fields. The corresponding search string was: (neuromarketing OR consumer neuroscience) AND (electroencephalography OR EEG) OR (event-related potentials OR ERP). This strategy yielded a total of 55,211 records prior to the removal of duplicates and the application of eligibility criteria.

The first screening stage was conducted directly within the databases by applying filters for the subject areas Management and Business, document type, open-access articles, and eligibility criteria related to language, publication year, and document type. This step resulted in the exclusion of 54,188 records. The remaining documents were then exported in BibTeX format.

All subsequent stages of the systematic review were conducted collaboratively by the reviewers using the Rayyan platform, which provides structured fields supporting all phases of the review process, from planning and screening to data extraction and analysis, thereby facilitating adherence to the systematic review protocol.

Study selection involved independent evaluations by the reviewers. The second screening stage consisted of removing duplicate records across databases, resulting in the exclusion of 12 articles. Consequently, 1,011 articles were deemed eligible for title and abstract screening. Figure 1 presents the results of the search and selection process.

Figure 1. PRISMA flow diagram of the study selection process.



Note: Twenty studies met the eligibility criteria. However, the final quantitative synthesis was based on 18 studies, following the exclusion of two statistical outliers (Vecchiato et al., 2014; Zanolie et al., 2015) identified during sensitivity analyses.

During the title and abstract screening, 466 articles were excluded for not aligning with the study's focus; although they addressed EEG, they were not empirical studies applying this technique to consumer behavior. As a result, 545 articles were deemed eligible for full-text review.

In the subsequent stage, detailed full-text assessment led to the exclusion of 407 studies, primarily because they did not examine physiological responses within a marketing context, leaving 138 articles for preliminary inclusion. Finally, following the application of the JBI Critical Appraisal Checklist for Quasi-Experimental Studies and verification of the availability of sufficient statistical data for effect size calculation, 118 studies were excluded, resulting in a final sample of 20 studies included in the quantitative synthesis.

Data Analysis

After sensitivity diagnostics, 18 independent studies were retained for quantitative synthesis. Table 1 summarizes the main methodological characteristics and individual effect sizes of the included studies. A predominance of within-subjects designs and the use of diverse EEG metrics can be observed,

reflecting the methodological heterogeneity of the field.

Table 1. Characteristics of the included studies.

Study (ID)	Total N	Study Design	Stimulus	EEG Metric	Cohen's d [95% CI]	Weight (%)
Pozharliev et al. (2022)	112	Between-subjects	Augmented Reality Advertising vs. Traditional	Alpha Power (Attentional Vigilance)	0.20 [0.01, 0.39]	25.9
Daugherty et al. (2018)	20	Within-subjects	TV Commercials (3 brands: Aeropostale, AT&T, State Farm)	Global Neural Activation (ERPs, 200–800 ms epochs)	0.48 [0.02, 0.95]	4.2
Nittono & Watari (2017)	32	Mixed	Food Images (with/without prior tasting)	LPP (Late Positive Potential) and P3	0.48 [0.12, 0.85]	6.8
Wajid et al. (2021)	17	Within-subjects	Social Media Video Ads (Emotional vs. Informational Appeal)	Frontal Alpha Asymmetry (PFA/GFPz)	0.52 [0.02, 1.03]	3.5
Wang et al. (2018)	21	Within-subjects	Product Rating Evaluations and Coupons	LPP (400–600 ms) and N2 (270–370 ms)	0.92 [0.41, 1.43]	3.5
Gerner et al. (2025)	20	Within-subjects	Interior Design Environments (Nature vs. Urban)	Frontal Theta/Beta Ratio (Attentional Control)	0.56 [0.09, 1.03]	4.1
Wei et al. (2024)	22	Mixed	Green Consumption: Message Framing (Positive/Negative)	LPP (600–800 ms) and P2 (190–250 ms)	0.69 [0.22, 1.15]	4.2
Goto et al. (2019)	36	Within-subjects	Product Images (High vs. Low Preference)	N200 (Attention) and LPP (Motivated Attention)	0.69 [0.33, 1.05]	6.9
Touchette & Lee (2017)	34	Within-subjects	Apparel Products (Attractive vs. Unattractive)	Frontal Alpha Asymmetry (F3/F4)	0.70 [0.32, 1.07]	6.4
Fudali-Czyż et al. (2016)	20	Within-subjects	Brand Extension (Congruent vs. Incongruent Names)	N270, P300, and N400 (Semantic Processing)	0.65 [0.16, 1.13]	3.9
Wang et al. (2021)	27	Within-subjects	Aquatic Product Images (Dynamic vs. Static)	LPP (Latency/Amplitude) and P2	0.79 [0.35, 1.22]	4.9
Ma et al. (2021)	25	Within-subjects	Mobile Payment vs. Cash (High/Low Price)	N270 (Cognitive Conflict) and P200	0.86 [0.40, 1.32]	4.3
Lee et al. (2014)	18	Within-subjects	Green vs. Conventional Product Messages	Frontal Theta Power (Cognitive Engagement)	0.95 [0.40, 1.51]	2.9
Vecchiato et al. (2011)	11	Within-subjects	TV Commercials (Pleasant vs. Unpleasant)	Frontal Alpha Asymmetry (Imbalance Index)	0.96 [0.25, 1.68]	1.8
(Ma et al., 2022)	22	Within-subjects	Framing Effects (Monetary Gain/Loss)	Outcome-Related Potentials (FRN/P300)	1.00 [0.49, 1.52]	3.4
(Gunawan et al., 2023)	30	Within-subjects	Logo Design (Visual Congruency)	Frontal Alpha Power (High Alpha)	0.09 [-0.27, 0.45]	7.0
Hsu & Chen (2020)	16	Within-subjects	Hotel Videos with Subliminal Stimuli (Emojis)	Spectral Power (Theta, Alpha, Beta)	1.41 [0.72, 2.11]	1.9
(Xie et al., 2014)	22	Within-subjects	Visual Metaphors (Spatial Position and Valence)	P200 (Attentional Detection)	0.55 [0.10, 1.00]	4.5

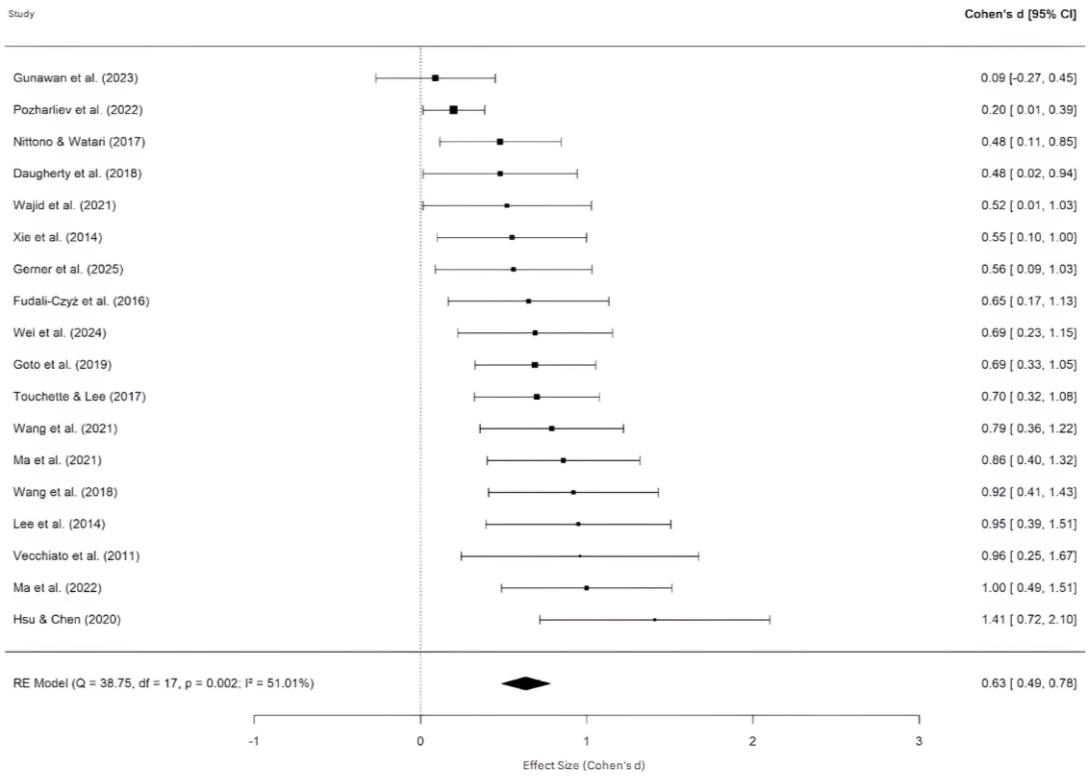
Source: Authors' own elaboration, 2026.

To ensure the robustness of the estimates, an influence diagnostic analysis was conducted. Based on Cook's distance, two studies (Vecchiato et al., 2014; Zanolie et al., 2015) were identified as exerting disproportionate influence on the overall effect estimate. These studies were excluded exclusively within the context of sensitivity analyses, resulting in a final analytical sample comprising 18 studies. The removal of these cases contributed to a reduction in heterogeneity to more controlled levels and to

the adjustment of the global effect estimate.

The meta-analysis conducted under a random-effects model estimated via REML revealed a statistically significant overall effect size (d = 0.63, p < .0001), corresponding to a medium-to-large magnitude. Residual heterogeneity was classified as moderate (I^2 = 51.01%). Figure 2 presents the forest plot with individual study estimates and the aggregated effect.

Figure 2. Forest plot displaying individual study effect size estimates and the aggregated overall effect.



Source: Authors' own elaboration, 2026.

The forest plot indicates that, despite variability across neural metrics and experimental paradigms, the studies converge toward a consistent positive effect, resulting in a medium-to-large overall effect size (d = 0.63). This finding supports the discriminative capacity and sensitivity of EEG in capturing systematic differences in consumer decision-making processes.

Moderator and Heterogeneity Analyses

To investigate the sources of the moderate heterogeneity observed in the global model (I^2 = 51.01%), meta-regression and subgroup analyses were conducted based on three theoretically grounded moderators: (a) type of neurophysiological metric (ERP vs. spectral), (b) nature of the experimental stimulus (static vs. dynamic), and (c) dominant psychological process under investigation (affective/motivational vs. cognitive/evaluative).

Meta-regression analyses indicated that the type of neurophysiological metric did not exert a significant moderating effect on the observed effect sizes (p = 0.35; R^2 = 0.00%). This finding suggests that time-domain approaches (event-related potentials - ERPs) and frequency-domain approaches (spectral metrics) exhibit comparable sensitivity in detecting neural differences associated with consumer behavior, reinforcing the methodological robustness of EEG regardless of the metric employed.

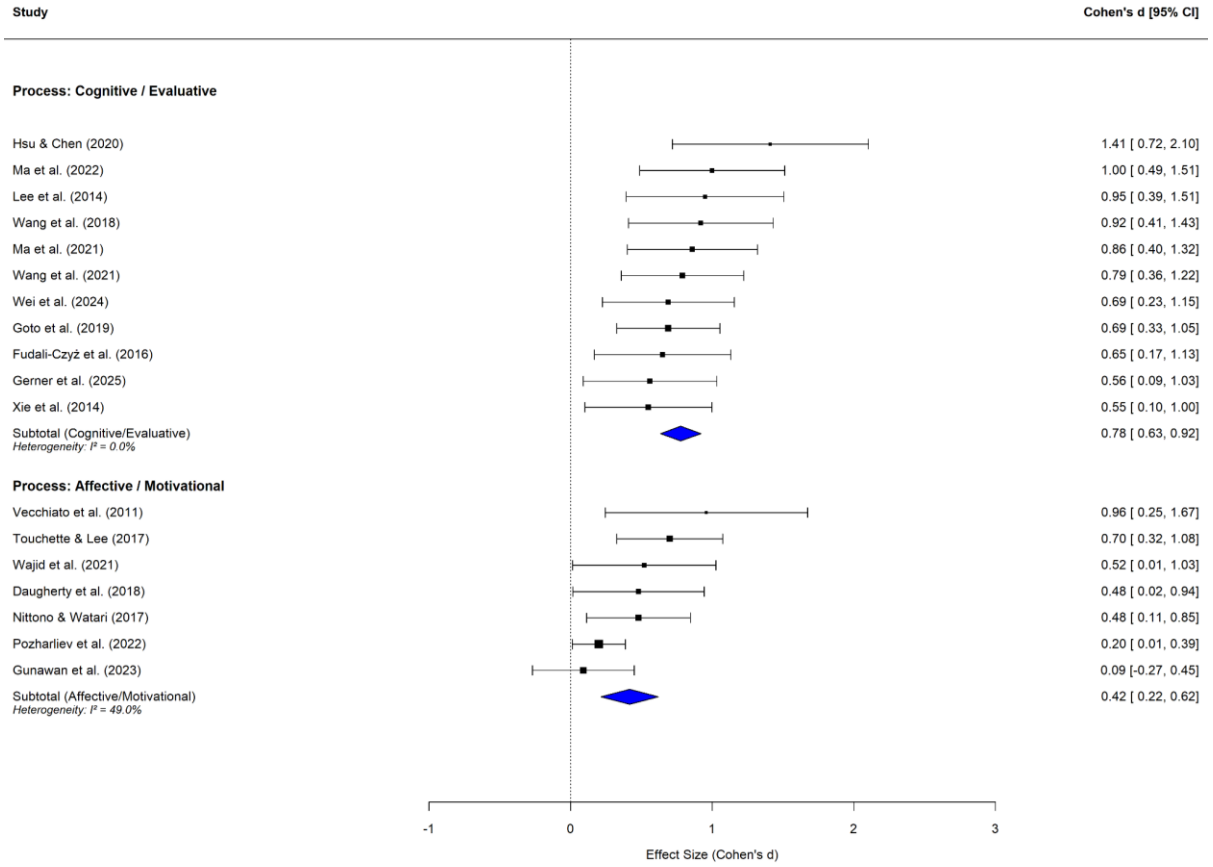
Similarly, the nature of the experimental stimulus accounted for only a modest proportion of the between-study variance (R^2 = 12.45%) and did not reach conventional levels of statistical significance (p = 0.18). Although a trend toward slightly larger effect sizes for dynamic stimuli relative to static stimuli was observed, this difference was insufficient to characterize stimulus type as a statistically robust moderator, possibly due to the limited number of studies within each category and the variability of experimental paradigms.

In contrast, the dominant psychological process investigated emerged as the primary explanatory source of the observed heterogeneity. Subgroup analyses revealed clear differences in both effect magnitude and consistency across studies. As illustrated in Figure 3, the Cognitive/Evaluative subgroup exhibited a large and statistically significant combined effect size (d = 0.78; 95% CI [0.63, 0.92]), accompanied by the absence of residual heterogeneity (I^2 = 0.0%), indicating high inter-study consistency.

Conversely, the Affective/Motivational subgroup showed a smaller, though positive and statistically significant, effect size (d = 0.42; 95% CI [0.22, 0.62]), with persistent moderate heterogeneity (I^2 = 49.0%). This pattern suggests that affective and motivational responses are more dependent on contextual, individual, and methodological factors, resulting in greater variability across studies.

Visually, the stratified forest plot (Figure 3) shows a systematic rightward shift of the combined effect diamond for the Cognitive/Evaluative subgroup relative to the Affective/Motivational subgroup, corroborating the substantive difference between the psychological domains examined. Taken together, these findings indicate that while EEG is an effective tool for investigating multiple processes underlying consumer behavior, its sensitivity and stability are particularly pronounced for cognitive and evaluative processes—such as attention, memory, and value integration—which exhibit more consistent and replicable neural patterns.

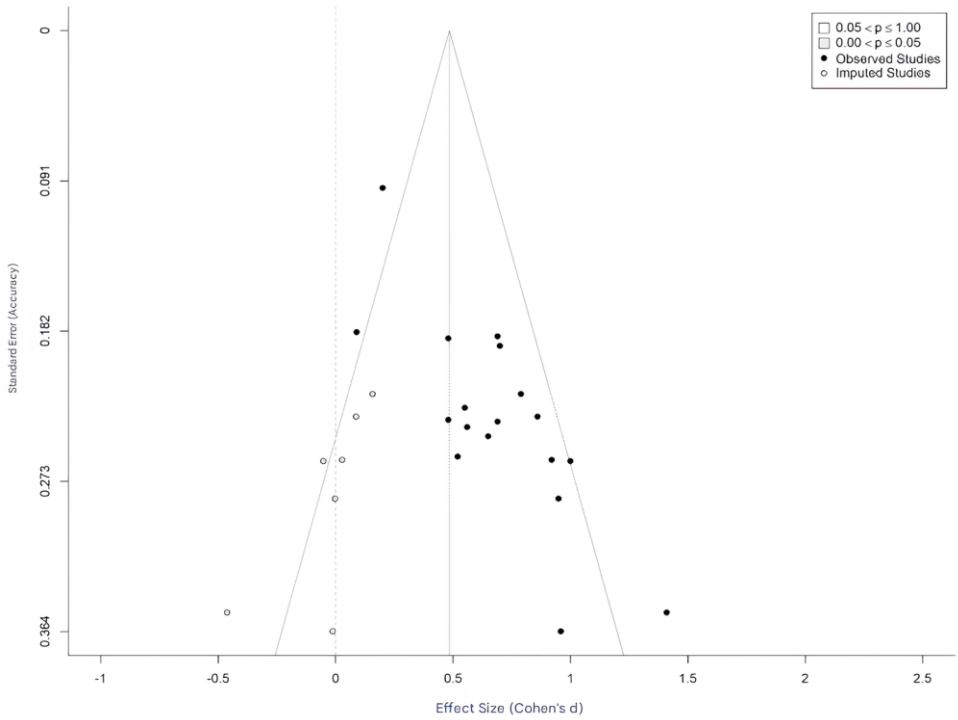
Figure 3. Stratified forest plot by dominant psychological process (Affective/Motivational vs. Cognitive/Evaluative).



Source: Authors' own elaboration, 2026.

Publication bias was assessed through visual inspection of the funnel plot, application of the Trim-and-Fill procedure, and calculation of Rosenthal's Fail-safe N. Visual inspection of the funnel plot (Figure 4) indicated the presence of moderate asymmetry, characterized by a lower density of studies on the left side of the distribution, particularly among those with lower precision. The Trim-and-Fill procedure identified a limited number of potentially missing studies, which were imputed to restore funnel plot symmetry. Importantly, even after the imputation of these theoretical studies, the overall distribution of effect sizes remained centered on positive values, with no substantial alteration to the observed pattern.

Figure 4. Funnel plot with Trim-and-Fill procedure.



Source: Authors' own elaboration, 2026.

After adjustment using the Trim-and-Fill method, the combined effect size remained statistically significant, although slightly reduced (d = 0.48; 95% CI [0.34, 0.63]; p < .0001), indicating that the observed asymmetry does not compromise the main conclusion of the meta-analysis. Rosenthal's Fail-safe N indicated that 239 null-effect studies would be required to render the result non-significant, a value that substantially exceeds the recommended critical threshold (5k + 10 = 100), suggesting moderate to high robustness of the findings. Taken together, these/ results indicate that although publication bias cannot be entirely ruled out, its magnitude is limited and insufficient to undermine the stability and reliability of the observed overall effect.

Discussion

The main quantitative results of the present meta-analysis are summarized in Table 2, which integrates the central indicators related to effect magnitude, the degree of heterogeneity across studies, and the robustness of the findings in the presence of potential publication bias. This systematization allows for a direct assessment of the extent to which the accumulated empirical evidence supports the theoretical propositions discussed in the neuromarketing literature, particularly with respect to the validity of EEG as a sensitive tool for investigating consumer behavior.

Table 2. Summary of the Main Findings of the Meta-Analysis

Analytical Dimension	Statistical Result	Interpretation and Implication
Effect Magnitude	$d = 0.63$, $p < .0001$ 95% CI [0.49, 0.78]	Medium-to-large effect size, indicating high sensitivity of EEG measures to discriminate differences in consumer processing.
Heterogeneity	$I^2 = 51.01\%$ $Q(17) = 38.22$, $p = .002$	Moderate heterogeneity, consistent with the diversity of neural metrics and experimental paradigms, yet accompanied by directional consistency of effects.
Robustness / Bias	Fail-safe $N = 239$ Trim-and-Fill: k imputed = 7 Adjusted $d = 0.48$	Evidence of limited publication bias. The combined effect remains statistically significant after adjustments, indicating stability of the findings.

Source: Authors' own elaboration, 2026.

As shown in Table 2, the observed overall effect size is of medium-to-large magnitude, accompanied by moderate heterogeneity and directional consistency of results, even in the presence of diverse neurophysiological metrics and experimental paradigms. Furthermore, publication bias analyses indicate that the observed asymmetry is limited and insufficient to compromise the significance of the combined effect, which remains statistically robust after adjustment procedures. Taken together, these findings reinforce the stability of the empirical evidence and support the interpretation that EEG-based measures reliably capture cognitive and affective processes relevant to consumer decision-making.

Theoretical Implications

The present meta-analysis offers a relevant theoretical advance by enabling a critical reappraisal of recurring concerns related to replicability and empirical consistency in the field of neuromarketing. The directional stability observed in the aggregated effects, even in the presence of moderate heterogeneity across studies, indicates that EEG-based neurophysiological markers capture theoretically meaningful group-level psychological regularities associated with cognitive and affective processes involved in consumer decision-making. These findings contrast with earlier interpretations that attributed observed empirical variability to an alleged theoretical fragmentation of the field.

Historically, part of the literature has characterized neuromarketing as being affected by a "consistency crisis," driven by divergent findings regarding the direction and statistical significance of specific EEG metrics. Byrne et al. (2022), for example, highlighted inconsistencies in the association between components such as the P200 and indicators of consumer preference, reinforcing the perception that such variability would undermine the validity of neurophysiological inferences in consumption contexts. The results of the present meta-analysis, however, do not support this interpretation. Rather, the identified heterogeneity should be understood less as evidence of theoretical fragility and more as an expected consequence of the methodological diversity inherent to a multidisciplinary field.

Neuromarketing studies differ substantially in terms of the nature of experimental stimuli, simulated consumption contexts, and neural signal preprocessing pipelines, including distinct strategies for filtering, spectral decomposition, and the definition of temporal windows (Khondakar et al., 2024; Alsharif & Isa, 2025). In this context, the observed variability in effect sizes reflects differences in the stages and levels of psychological processing under investigation, rather than the absence of a shared underlying phenomenon. The directional consistency of effects observed despite these differences supports the existence of common functional mechanisms that cut across distinct metrics and

paradigms.

The main theoretical contribution of this meta-analysis therefore lies in the consolidation of a unified interpretative framework in which EEG-derived metrics functionally converge toward the detection of states associated with affective valence, motivational relevance, and approach–avoidance orientation. Regardless of whether they are extracted in the frequency or time domain, these measures capture complementary facets of a dynamic, multiphasic, and distributed decision-making process underlying consumer behavior. Such convergence supports the plausibility of an integrated model of consumer decision-making in which empirical variability and functional consistency coexist.

Within the frequency domain, the findings reinforce the role of frontal alpha asymmetry (FAA) as a functionally consistent indicator of motivational orientation toward approach and avoidance. Previous evidence has identified FAA as one of the most theoretically established metrics for discriminating positive and negative affective responses (Byrne et al., 2022), and the meta-analytic results indicate that this validity is preserved across a wide range of experimental paradigms. In consumption contexts, patterns of left frontal activation are systematically associated with greater stimulus pleasantness and attractiveness, whereas inverse patterns reflect avoidance tendencies (Vecchiato et al., 2011; Touchette & Lee, 2017). Results obtained in ecologically distinct environments, such as digital advertising and social media campaigns, further reinforce the functional consistency of FAA as a marker of motivational orientation (Cartocci et al., 2017; Wajid et al., 2021; Zito et al., 2021).

Complementarily, in the time domain, event-related components such as the P300 and the late positive potential (LPP) demonstrate consistent associations with attentional allocation, stimulus relevance, and emotional evaluation processes. The P300 has been widely linked to the prioritization and categorization of relevant information, showing sensitivity to stimulus congruency and perceived significance for consumers (Fudali-Czyż et al., 2016; Nittono & Watari, 2017; Shang et al., 2024). The LPP, in turn, reflects sustained emotional processing and the intensity of motivational relevance, maintaining robust relationships with brand preference, emotional arousal, and purchase intention (Bosshard et al., 2016; Liao et al., 2019; Wang et al., 2021; Ma et al., 2021). Together, these components capture distinct yet interdependent temporal stages of the decision-making process, ranging from the initial detection of relevance to the affective elaboration that precedes choice.

Additionally, the statistical robustness observed in the aggregated effects provides a consistent counterargument to criticisms that neuromarketing findings are predominantly inflated by publication bias or characterized by ephemeral effects. Although asymmetry analyses indicate the possibility of limited bias, the maintenance of statistical significance after adjustment procedures and the magnitude of the Fail-safe N suggest that such biases are insufficient to undermine the main conclusion. These results converge with recent bibliometric analyses documenting a progressive increase in methodological rigor and analytical sophistication in neuromarketing research over the past decade (Wang et al., 2024; Alsharif & Isa, 2025).

Overall, the principal theoretical contribution of this meta-analysis lies in demonstrating that heterogeneity in EEG-based findings reflects functional specialization across different stages of consumer decision-making rather than theoretical fragmentation of the field. Accordingly, variability in the neuromarketing literature should not be interpreted as disorganizing methodological noise, but as the expression of theoretically meaningful differences in the psychological processes under investigation.

The functional convergence between time-domain and frequency-domain metrics supports a more integrated understanding of consumer decision-making, in which multiple neurophysiological markers capture complementary and interdependent stages of cognitive and emotional processing. By confirming this complementarity and the directional stability of effects, the present study contributes to the theoretical consolidation of neuromarketing and provides a more precise conceptual foundation for

the scientific use of EEG in consumer behavior research.

Managerial Implications

The findings of this meta-analysis offer relevant implications for marketing research and managerial decision-making by providing quantitative evidence on when EEG-based measures can generate complementary insight beyond declarative methods. More specifically, the observed overall effect size, of moderate-to-large magnitude (d = 0.63), indicates that electroencephalography (EEG)-based metrics show consistent sensitivity in discriminating implicit consumer responses at the group level. This finding helps explain a recurring market phenomenon in which products and campaigns that perform well in declarative research produce unsatisfactory outcomes after market launch, partly because self-report measures remain vulnerable to social desirability bias, ex post rationalization, and introspective limitations.

Converging evidence from the literature suggests that EEG can provide incremental informational value in the assessment of preferences and consumption intentions, particularly by accessing affective, attentional, and motivational states that are not fully captured by declarative measures (Baldo et al., 2015; Boksem & Smidts, 2015; Telpaz et al., 2015; Hakim et al., 2021). In this sense, the results of the present meta-analysis indicate that EEG is best understood as a complementary strategic resource for marketing research, especially useful in decisions characterized by higher financial risk and elevated uncertainty, such as copy testing, packaging validation, concept evaluation, brand communication, and pricing strategy. In such contexts, EEG may reduce the uncertainty associated with decisions based exclusively on self-reported data (Ohme et al., 2010; Venkatraman et al., 2015; Matukin et al., 2016).

At the same time, the findings also delineate important boundary conditions for the managerial use of EEG. Although EEG demonstrates consistent sensitivity for capturing implicit processes, its application may yield lower marginal informational returns in contexts in which consumption decisions are predominantly deliberative and strongly mediated by technical, normative, or regulatory criteria, such as complex B2B purchases or decisions involving low emotional involvement. Under such conditions, the additional gains over traditional methods may be modest and may not always justify the operational, analytical, and interpretive costs associated with neurophysiological measures.

Moreover, managerial interpretation of EEG signals requires caution. Neurophysiological metrics capture functional correlations associated with affective and cognitive states, but they do not, in isolation, allow for the identification of the specific causal mechanisms underlying observed responses. Accordingly, the use of EEG in decision-making processes presupposes specialized analytical expertise and its integration with complementary methods—such as eye tracking and behavioral measures—in order to translate neural responses into actionable insights for design, communication, and consumer experience (García-Madariaga et al., 2019; Ausin-Azofra et al., 2021).

At the applied level, specific metrics provide differentiated managerial insights. Frontal alpha asymmetry (FAA), for example, offers consistent indications of consumers' motivational orientation (approach versus avoidance) and is particularly useful for assessing initial affective responses to brand stimuli, layouts, and communication. Time-domain components such as the late positive potential (LPP), in turn, inform the depth of emotional processing and the sustained motivational relevance of stimuli, with direct implications for branding strategies, memorability, and advertising recall (Vecchiato et al., 2011; Touchette & Lee, 2017; Ma et al., 2021). In pricing contexts, specific patterns of prefrontal activation have been associated with willingness to pay and the subjective experience of the "pain of paying," enabling prospective testing of pricing alternatives prior to large-scale investments (Ramsøy et al., 2018; Wang et al., 2022).

In parallel, recent technological advances—including the greater availability of portable devices, cost reductions, improvements in signal quality, and the optimization of sample sizes—substantially enhance

the practical feasibility of these applications in real organizational contexts. Such developments increasingly position EEG as a cost-effective alternative for mitigating decision-making risks in competitive and high-uncertainty environments (Hakim et al., 2021; Vozzi et al., 2021; Ishtiaque et al., 2025).

Taken together, the findings indicate that EEG is most appropriately understood as a complementary resource for marketing research and managerial decision-making, rather than as a standalone predictive instrument. By capturing implicit information related to motivation, attention, memory, and subjective valuation, neurophysiological metrics can provide additional support in contexts where cognitive and affective responses play a central role. In this sense, EEG enhances—rather than replaces—traditional marketing research methods, expanding organizations' capacity to interpret and anticipate consumer responses under conditions of uncertainty.

Neural Indicators of Attention and Emotional Engagement in the Interpretation of the Overall Effect

A closer examination of the studies included in this meta-analysis indicates that the observed neural effects reflect distinct yet complementary targets of consumer response, ranging from early attentional processes to mechanisms of emotional engagement and motivational relevance. This conceptual heterogeneity is central to the correct interpretation of the aggregated effect size ($d = 0.63$), which should not be understood as a direct neural marker of choice, but rather as the integration of responses associated with multiple stages of consumers' psychological processing.

A substantial subset of the included studies operationalizes the impact of marketing stimuli through neural indicators of attention, perceptual salience, and early information processing. Specifically, early event-related potential (ERP) components such as P2 and N2/N270, as well as modulations in alpha-band activity, have been widely employed as proxies for cognitive resource allocation, stimulus relevance detection, and conflict monitoring. Representative examples include Xie et al. (2014), who used the P200 to index attentional detection of visual metaphors; Ma et al. (2021), who associated the N270 with cognitive conflict in payment decisions; and Fudali-Czyż et al. (2016), who employed N270, P300, and N400 to capture semantic incongruence in brand extensions.

Converging evidence from studies based on spectral metrics, such as frontal alpha power, also indicates that these measures primarily reflect states of attentional vigilance and cognitive control rather than explicit evaluations of preference. This pattern is observed, for example, in Pozharliev et al. (2022), who analyzed alpha-band modulation in augmented reality advertising contexts, and in Gunawan et al. (2023), who linked frontal alpha power to cognitive engagement in logo design tasks.

It is essential to emphasize that attention should not be conflated with preference. Although highly salient stimuli recruit additional cognitive resources, such neural responses primarily index the intensity of stimulus processing, functioning as necessary, but not sufficient, conditions for subsequent value evaluations and choice. This distinction is reinforced by studies within the present corpus, such as Goto et al. (2019), who demonstrated that the N200 reflects task-oriented selective attention modulated by subjective preference, while operating predominantly at the attentional level.

Beyond early attentional processes, a second set of studies focuses on mechanisms of emotional engagement and motivational relevance, traditionally captured by late ERP components and spectral metrics associated with affective valence. Within this domain, the late positive potential (LPP) emerges as the most recurrent indicator. Studies by Nittono and Watari (2017), Wang et al. (2018), Wei et al. (2024), and Wang et al. (2021) demonstrate that the LPP indexes sustained attentional effort and motivational significance attributed to emotionally relevant stimuli, including food images, products, green consumption messages, and dynamic visual stimuli.

These studies consistently show that stimuli associated with positive emotional content or personal relevance elicit stronger LPP responses, which are often associated with more favorable evaluations and greater purchase predisposition. Nevertheless, such effects should be interpreted as reflecting intensified motivational engagement rather than as direct determinants of choice behavior, as they do not replace subsequent deliberative processes.

In an integrated manner, frontal alpha asymmetry has been consistently associated with motivational tendencies of approach and avoidance in consumption contexts. Empirical evidence from Touchette and Lee (2017), Vecchiato et al. (2011), and Wajid et al. (2021) indicates that greater left frontal activation is related to higher perceived attractiveness, emotional appeal, and approach predisposition toward products, advertisements, and audiovisual stimuli.

Extending this perspective, studies linking neural responses to economic valuation suggest that metrics based on asymmetry and spectral power, particularly in higher frequency bands, exhibit probabilistic capacity to discriminate willingness to pay. Evidence in this regard is observed in Ma et al. (2012), who analyzed neural responses to monetary gain–loss framing, and in Hsu and Chen (2020), who demonstrated spectral modulations associated with implicit value evaluation in hotel videos with subliminal stimuli.

These distinctions are central to interpreting the overall effect size observed in this meta-analysis. The aggregated effect ($d = 0.63$) does not represent a direct neural approximation of consumer choice, but rather integrates neural responses associated with both attentional capture and perceptual salience (e.g., Xie et al., 2014; Ma et al., 2021; Goto et al., 2019) and the intensity of emotional and motivational engagement (e.g., Nittono & Watari, 2017; Touchette & Lee, 2017; Wang et al., 2021).

Consequently, the magnitude of the effect should be understood as an indicator of the effectiveness of marketing stimuli in recruiting multiple stages of consumer processing, which cumulatively increase the likelihood of favorable evaluations and positive decisions. This interpretation is consistent with contemporary models of decision-making, in which early attentional responses and subsequent affective reactions operate in an integrated manner, influencing, but not independently determining, choice behavior.

Limitations and Future Research Directions

Although this meta-analysis represents a relevant advance by providing an unprecedented quantitative synthesis of EEG applications in consumer behavior research, its results should be interpreted in light of methodological limitations inherent both to the study design and to the developmental stage of the field itself. These limitations do not invalidate the evidence presented, but they delimit the scope of possible inferences and provide important guidance for future research agendas.

Study Limitations

A central limitation concerns the quality and completeness of statistical reporting in the primary studies. Despite the growing methodological sophistication observed in recent literature, a substantial number of potentially eligible articles had to be excluded due to the absence of essential inferential statistics, such as effect sizes or sufficient information for their estimation. This limitation highlights persistent challenges related to standardization, transparency, and reproducibility of scientific reporting in neuromarketing, thereby constraining the breadth of the quantitative synthesis achievable in the present study.

In addition, although the included studies span different decision-making contexts, such as advertising, branding, and pricing, the final number of eligible articles ($k = 18$) did not allow for subgroup analyses with adequate statistical power. As a consequence, it was not possible to systematically examine variations in effect magnitude across stimulus types, specific neural metrics, or distinct domains of

consumer decision-making. This limitation restricts more fine-grained inferences regarding the differential applicability of EEG across decision contexts.

Directions for Future Research

In light of these limitations, several priority directions emerge for the theoretical and methodological advancement of the field. First, future research would benefit from greater convergence in statistical reporting practices, including the systematic disclosure of effect sizes, confidence intervals, and complete inferential metrics. Such standardization is a necessary condition for enabling more granular meta-analyses, robust comparisons across neural markers, and more precise assessments of effect consistency.

Second, enhancing ecological validity represents a central challenge for subsequent investigations. The predominance of highly controlled laboratory designs in the current literature limits the generalizability of findings to real-world consumption contexts, which are characterized by greater complexity, multitasking, and environmental noise. Studies exploring the use of portable EEG systems in naturalistic settings, such as physical retail environments, digital platforms, or immersive experiences, may contribute to evaluating the stability and robustness of neural effects under conditions more closely aligned with everyday decision-making.

Finally, future research should advance the identification of theoretically relevant moderators by investigating whether the sensitivity, explanatory utility, and predictive value of EEG-based markers vary systematically across different types of decisions. Comparisons between predominantly affective decisions, such as advertising and branding, and more deliberative or utilitarian evaluations, such as pricing and technical attributes, represent a promising avenue for more precisely delineating the explanatory scope of EEG in understanding consumer behavior.

Taken together, these limitations and future directions indicate that EEG-based neuromarketing is undergoing a process of progressive consolidation. Methodological advances, combined with more ecologically valid and theoretically grounded investigations, are likely to enhance the precision, interpretability, and relevance of neural inferences, strengthening the role of EEG as a scientific tool for investigating consumer decision-making.

Conclusion

This study examined whether cumulative EEG evidence in consumer research is sufficiently consistent to support its use in marketing research and decision-making. Based on 18 experimental studies retained after influence diagnostics, the meta-analysis found a positive and statistically significant overall effect of medium-to-large magnitude ($d = 0.63$; 95% CI [0.49, 0.78]), with moderate heterogeneity ($I^2 = 51.01\%$). After adjustment for potential publication bias using the Trim-and-Fill procedure, the effect remained positive and significant ($d = 0.48$; 95% CI [0.34, 0.63]), and Rosenthal's Fail-safe N further supported the robustness of the findings. Taken together, these results indicate that the main conclusion is not explained solely by publication asymmetry or by a small number of influential studies.

EEG shows overall discriminative sensitivity at the group level in consumer research, but this sensitivity is not uniform across psychological processes. Cognitive and evaluative studies yielded a larger and highly consistent effect ($d = 0.78$; 95% CI [0.63, 0.92]; $I^2 = 0.0\%$), whereas affective and motivational studies showed a smaller and more variable effect ($d = 0.42$; 95% CI [0.22, 0.62]; $I^2 = 49.0\%$). Thus, the heterogeneity observed in the literature appears to reflect not only methodological variation but also theoretically meaningful differences in the processes captured by EEG. More specifically, the evidence is stronger for attention, cognitive evaluation, conflict detection, and value integration, whereas affective and motivational responses remain more dependent on individual,

contextual, and methodological conditions.

These findings help move the literature beyond a generic characterization of EEG results as "mixed" by clarifying the conditions under which the method is more or less consistent. At the same time, EEG should not be interpreted as a direct neural indicator of preference, choice, or any single mechanism underlying consumer behavior. Rather, it is best understood as a complementary method whose value is especially relevant in pretests of advertisements, products, packaging, brand communications, and pricing cues, particularly when implicit attentional, affective, or motivational responses are theoretically important. For this reason, managerial decisions should integrate EEG with behavioral outcomes, self-report measures, eye tracking, and contextual evidence to determine whether neural differences translate into preference, purchase intention, or market behavior.

These conclusions remain limited by the small number of eligible studies, incomplete statistical reporting in several potentially relevant articles, variation in EEG acquisition and preprocessing procedures, and the predominance of controlled laboratory settings. Future research should preregister neurophysiological outcomes, report complete effect-size information, standardize EEG preprocessing pipelines, and test whether EEG adds predictive accuracy beyond self-reports and behavioral measures in more ecologically valid consumption environments.

Overall, EEG should be regarded neither as a standalone predictor of consumer choice nor as an isolated technological promise, but as a methodologically valuable complementary resource whose contribution depends on the psychological process under investigation, the quality of the experimental design, and its integration with other sources of consumer evidence.

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