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Research Article

Neurophysiological Correlates of Consumer Responses: A PRISMA-Based Meta-Analysis

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Abstract

Aim: Consumer neuroscience increasingly integrates neurophysiological measurement with self-report methods, yet a comprehensive quantitative synthesis across different neurophysiological modalities within a common meta-analytic framework has remained limited. This meta-analysis systematically evaluates the association between EEG, eye-tracking, galvanic skin response (GSR), and multimodal measures and consumer outcomes (purchase intention, brand attitude, advertisement evaluation, and preference) reported in empirical studies published between 2010 and 2024. **Materials and Methods:** Following PRISMA 2020 guidelines, 3,109 records were screened, resulting in 22 primary studies included in the final analysis. Effect sizes were synthesized in two independent pools (standardized mean differences and Fisher z-transformed correlations) using random-effects models (REML with Knapp-Hartung adjustment). **Results:** The pooled effect sizes were moderate and statistically significant (SMD: d = 0.47, 95% CI [0.18, 0.75]; correlation: r ≈ 0.33, 95% CI [0.07, 0.61]), with high heterogeneity observed across studies (I^2 = 77.3%-84.1%). None of the tested moderators reached statistical significance after FDR correction. Publication bias was detected in the SMD pool, but corrected estimates remained significant. **Conclusion:** Neurophysiological measures provide meaningful but context-dependent insights into consumer behavior, functioning as complementary rather than universal predictors whose explanatory value varies depending on stimulus characteristics, measurement modality, and experimental design.

Keywords: Consumer Neuroscience, Meta-Analysis, EEG, Eye-Tracking, GSR.

Ethics committee approval: There is no need for ethics committee approval.

Introduction

Self-report-based measures have long served as the dominant method for explaining consumer behavior. Findings accumulated over the past four decades in cognitive psychology and decision neuroscience indicate, however, that consumer decisions are largely guided by automatic, emotional, and implicit processes [1,2]. This theoretical shift has rendered the explanatory power of self-report scales questionable and has highlighted the need for methods capable of directly observing the unconscious mechanisms that mediate decision-making. Neurophysiological measurement approaches derive their significance precisely from this theoretical gap, proposing a methodological extension to marketing research with the promise of capturing what consumers cannot articulate.

Theoretical Framework

Dual-process theory holds that cognition comprises two interacting modes: the fast, automatic, and emotionally laden System 1, and the slow, controlled, and analytical System 2 [2,3]. Given that a substantial proportion of consumer decisions involves low-involvement and high-frequency choices, it is generally accepted that these decisions are predominantly executed through System 1 patterns. Processes such as in-store product selection, immediate emotional responses to advertising, and the appraisal of brand associations frequently produce evaluative patterns that operate implicitly and under time pressure, rather than through deliberate reasoning. This theoretical foundation suggests that consumer responses cannot be fully captured through reported attitudes and intentions alone.

The somatic marker hypothesis grounds the priority of emotion over the decision-making process within a neurobiological framework [1]. According to the hypothesis, choice alternatives are tagged by bodily-emotional feedback patterns before cognitive deliberation is complete, and these markers assume a determining role in guiding the decision. Bechara et al. [4] demonstrated in the Iowa Gambling Task that healthy participants were able to anticipate disadvantageous card decks through anticipatory electrodermal responses before they could cognitively recognize them. This finding directly supports the theoretical claim that emotional-bodily signals precede explicit knowledge, and legitimizes the search for an analogous priority pattern in the formation of consumer preferences.

The systematic limitations of self-report measures stem from the intrinsic constraints of introspection as a data source. Nisbett & Wilson [5] argued that direct introspective access to higher cognitive processes is limited and that verbal reports are largely based on reconstructions of implicit causal theories. In consumer research, the same limitation materializes as social desirability bias, demand characteristics, and recall biases, manifesting in empirical patterns such as the intention–behavior gap and the inconsistency between in-the-moment preferences and remembered preferences. Zaltman [6] contended that consumers cannot verbally express the greater part of their thought processes, placing this claim at the center of the methodological debate in marketing research.

When the dual-process model, the somatic marker hypothesis, and the constraints of introspection are considered together, the conclusion is reached that consumer responses cannot be adequately sampled through verbal report alone, and that non-verbal, stimulus-concurrent, and high-resolution data sources must be added. Neurophysiological measurement directly responds to this need: rather than invalidating self-report, it provides a complementary layer of evidence [7,8]. The conceptual grounding of this meta-analysis lies precisely in this synthesis; whether neurophysiological and declarative measures form a parallel pattern must be established through systematic aggregation of the empirical evidence in the field.

Neurophysiological Methods and the Measurement of Consumer Responses

The measurement methods used in consumer neuroscience cluster around three primary families that record different layers of cognitive and emotional processing at varying temporal and spatial resolutions. The first of these families is electroencephalography (EEG), which directly monitors the brain's electrical activity; the second is eye-tracking, which quantifies the allocation of visual attention at the stimulus level; and the third is electrodermal (GSR/EDA) measurement, which captures the bodily expression of sympathetic arousal. Each method can estimate a particular dimension of consumer response — motivational orientation, attentional allocation, or emotional arousal — with discriminant power, yet none can independently account for the holistic structure of a decision. Current consumer neuroscience literature has consequently shifted toward multimodal designs in order to transcend the interpretive limitations of single-modality measurement [9,10].

EEG has emerged as the most widely used neurophysiological method in consumer research owing to its high temporal resolution (millisecond level), relatively low cost, and field applicability. The frontal alpha asymmetry model proposed that left-dominant prefrontal activation indexes approach motivation while right-dominant activation indexes withdrawal motivation, thereby establishing the electrophysiological signature of affective orientation [11,12]. At the level of frequency bands, theta oscillations have been associated with conflict monitoring and value comparison, alpha with relaxation and attentional reduction, and gamma with feature binding and contextual integration. Among event-related potentials, the late positive potential (LPP) reflects the motivational salience of a stimulus from approximately 400 ms onward and has been linked to outcomes such as purchase intention and brand evaluation [13].

Eye-tracking quantifies the allocation of visual attention in considerable detail through the measurement primitives of oculomotor behavior. Fixation count, fixation duration, saccade amplitude, and area-of-interest transitions serve as direct indicators of the cognitive resources devoted to a given stimulus. The eye-mind hypothesis holds that gaze position maintains a strong correspondence with the content being processed at that moment, and this hypothesis has received broad empirical support in applied contexts such as package design, the visual hierarchy of advertisements, shelf layout, and digital interface interaction. Wedel & Pieters [14] presented a theoretical and methodological synthesis of eye-tracking research in marketing, systematically establishing the predictive power of visual attention within the consumer behavior literature.

Electrodermal activity records changes in the secretion level of eccrine sweat glands, the sole effector of the sympathetic nervous system, and thereby offers what can be characterized as a “pure sympathetic” measure of arousal. Tonic skin conductance level (SCL) reflects the general level of arousal, while phasic skin conductance response (SCR) reflects the stimulus-specific response [15,16]. In the consumer context, electrodermal measurement is used to capture emotional intensity during advertising exposure, anticipatory violation in product experience, and anticipatory responses prior to decision-making. Methodological limitations of the technique include its relatively slow response latency (1–3 second delay), sensitivity to environmental noise, and individual baseline differences, which create interpretive ambiguity when used in isolation.

The interpretive ambiguities inherent in each single-modality measure constitute the primary rationale for the proliferation of multimodal designs. For instance, an elevated SCR response can signal either positive excitement or negative anxiety; the measurement becomes meaningfully interpretable only when contextualized by simultaneous frontal EEG asymmetry or facial expression data. Within the framework of convergent validity, measuring the same theoretical construct with multiple methods reduces measurement error and strengthens theoretical interpretation. Venkatraman et al. [17] compared six distinct neurophysiological methods applied to the same set of advertisements and demonstrated that neurophysiological measures explained significant additional variance in advertising elasticity beyond conventional survey-based predictions. This finding empirically supports both the theoretical rationale for a multimodal approach and the necessity of evaluating different modalities jointly in meta-analytic synthesis [7].

The absence of a common reporting standard in consumer neuroscience leads to methodological choices varying from study to study — in stimulus duration, reference electrode, artifact-rejection threshold, and fixation threshold — and thereby undermines the aggregability of the literature. This variability directly contributes to the heterogeneity observed in meta-analytic synthesis [18,8]. The adoption of common reporting frameworks as the field matures stands as a methodological imperative that will enhance both the comparability of individual studies and the interpretive power of quantitative synthesis.

The Development of the Neuromarketing Field and the Accumulation of Empirical Evidence Consumer neuroscience established its distinct disciplinary identity in the early 2000s through functional magnetic resonance imaging studies, and over the past two decades it has become a rapidly growing component of both academic and applied marketing research as EEG, eye-tracking, and electrodermal measurement evolved into field-compatible tools [19,18]. The special issue devoted to consumer neuroscience by the Journal of Marketing Research in 2015 is regarded as a threshold marker of the field’s academic maturity; the proliferation of interdisciplinary organizations and special issues signals that neurophysiological methods have acquired a legitimate infrastructure in consumer research.

Bibliometric and conceptual reviews of the field indicate that publication volume has grown markedly over the past decade and that research has coalesced around a core focused on the relationship between neurophysiological signals and outcomes such as advertising effectiveness, brand attitude, purchase intention, and product preference [9,20]. Lim [20] provided a conceptual, methodological, and ethical map of the neuromarketing field and systematically delineated its disciplinary boundaries. Alsharif et al. [9] conducted a bibliometric analysis of the preceding five years, documenting that EEG is the most widely used instrument, followed by eye-tracking and electrodermal measurement. Kalaganis et al. [10] presented a comprehensive review centered on hybrid EEG schemes and assessed the field's future methodological directions around the theme of unconscious consumer bias. Hsu [21] adopted a managerial perspective, charted an application map for the field, and discussed the transfer pathways of academic findings to marketing practice.

One of the central debates in the literature concerns the degree to which neurophysiological measures provide incremental predictive power beyond traditional self-report measures. Venkatraman et al. [17] and Boksem & Smidts [13] demonstrated that neural measures could significantly predict advertising and film success beyond what traditional measures could account for. These findings were, however, generated against relatively small samples in individual studies, heterogeneous measurement protocols, and the risk of publication bias. The absence of a shared quantitative estimate of the field's overall effect size sustains uncertainty regarding the generalizability of individual findings and underscores the need for systematic quantitative synthesis.

Existing reviews have been conducted largely in the form of conceptual and qualitative surveys, with evidence for the quantitative pooling of effect sizes remaining limited. This meta-analysis undertakes a systematic synthesis, within the PRISMA 2020 framework, of 22 primary studies linking neurophysiological measures to consumer outcomes over the 2010–2024 window. The study has three primary objectives. The first is to estimate the pooled effect size of the association between neurophysiological measures and consumer responses in parallel pools of standardized mean differences and Fisher z-transformed correlations. The second is to evaluate, via meta-regression, the degree of cross-study variability and the extent to which this variability is explained by the moderators of publication year, sample size, and neurophysiological technique. The third is to test the robustness of the pooled estimates against sensitivity analyses and publication bias assessments.

When these three objectives are considered jointly, the study aims to provide a quantitative snapshot of the accumulated empirical evidence in consumer neuroscience and to document the sources of heterogeneity in the field through moderator analyses.

This study makes three primary contributions to the literature. First, it provides a quantitative synthesis of neurophysiological and consumer response relationships across multiple modalities, addressing the fragmentation in existing research. Second, it introduces a dual-effect size framework by jointly analyzing standardized mean differences and correlation-based effects, offering a more robust estimation approach. Third, it highlights the context-dependent nature of neurophysiological effects, demonstrating that their predictive value varies across experimental conditions rather than operating as a universal mechanism.

Materials and Methods:

There is no need for ethics committee approval.

This meta-analysis was conducted in accordance with the PRISMA 2020 guidelines [22]. The goal was to identify empirical studies published in English between 2010 and 2024 that examined the association between consumer behavior or attitudinal responses (purchase intention, brand attitude, emotional response) and neurophysiological measures (EEG, eye-tracking, GSR, and multimodal combinations thereof). An identical keyword block was applied across three databases: PubMed (E-utilities API, Title/Abstract/MeSH), OpenAlex (REST API, broad full-text search), and Scopus (web interface, TITLE-ABS-KEY field). A targeted second pass at the DOI level was conducted via OpenAlex to compensate for certain marketing and consumer journals deemed likely to remain under-represented in the primary query. The final query was executed on April 23, 2026; a total of n = 3,409 records were retrieved from the three databases, and after deduplication (DOI exact match + title similarity ≥ 0.92) n = 3,109 unique records were passed to the title/abstract screening stage. A detailed view of the search flow is presented in Figure 1. To enhance transparency and replicability, the study followed PRISMA 2020 reporting standards, including systematic screening, dual-reviewer validation, and structured data extraction procedures. These steps were implemented to minimize selection bias and ensure methodological consistency across included studies.

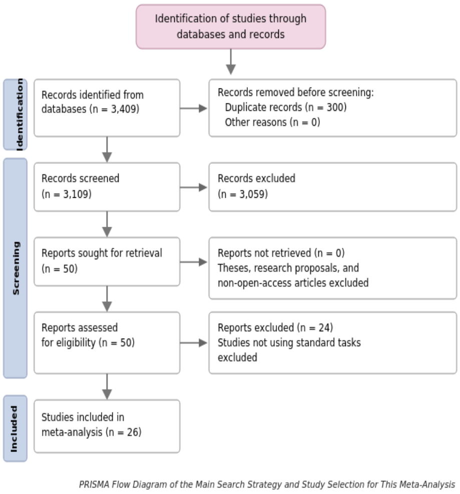

Figure 1: PRISMA 2020 flow diagram.

Inclusion criteria were organized under five headings. First, studies were required to be peer-reviewed empirical works published in English between 2010 and 2024. The second criterion was that they include at least one neurophysiological measure (EEG, eye-tracking, GSR, or a combination of these methods). Third, at least one consumer outcome (purchase intention, brand attitude, advertisement evaluation, emotional response) was required to have been reported. The fourth criterion was the availability of statistical reporting permitting standardized effect size computation (means and SDs, t, F, r, d, or equivalent). Finally, experimental or quasi-experimental designs conducted in laboratory or naturalistic settings were included. Exclusion criteria encompassed the following: review articles, book chapters, theses, and unpublished works; studies involving animal subjects or clinical populations; theoretical or simulation-based studies containing no empirical consumer measurement; and studies from which no effect size could be derived from the reported statistics.

Records were screened in a two-stage process (title/abstract → full text) by two independent researchers, with disagreements resolved by consensus. For each eligible study, a structured coding table was populated with: author information and DOI; sample characteristics (N, age group, proportion of female participants, country); methodological features (neurophysiological technique, stimulus type, within-subjects/between-subjects design); outcome definition and reported statistics; and effect size estimate and sampling variance. The coding process was systematized with an independent verification mechanism conducted by the second researcher, and in cases of disagreement in effect size derivation, consensus was reached by returning to the primary source.

Since the included studies reported their results according to two different statistical families, effect size coding was handled in two separate pools: standardized mean difference (SMD, Cohen's d) for mean differences, and Fisher z-transformed Pearson correlation (r) for continuous variable associations. SMD values were derived — when not directly reported — from t or F statistics or from group means and standard deviations using the standard conversion formulae proposed by Borenstein et al. [23]. For within-subjects designs, $d_z = t/\sqrt{n}$ and $v = 1/n + d_z^2/(2n)$ were used; for correlation studies, $v = 1/(n - 3)$ was used. All effect sizes were coded in a standardized direction such that positive values indicate the direction "stronger neurophysiological response ↔ stronger or more favorable consumer outcome."

Pooled estimates for the SMD and correlation pools were obtained using separate random-effects models fitted with restricted maximum likelihood (REML; 24), with the Knapp–Hartung correction applied to accommodate small study numbers [25]. Heterogeneity was assessed using Cochran's Q, the between-study variance estimate τ^2, and the I^2 statistic; I^2 thresholds were interpreted following the recommendations of Higgins et al. [26].

The robustness of the pooled estimates was tested using two complementary approaches: (i) a leave-one-out analysis, in which each study was successively excluded and the pooled estimate recomputed, and (ii) a Baujat diagram mapping each study's contribution to heterogeneity against its weight in the pooled estimate [27]. Publication bias was assessed through three complementary approaches: contour-enhanced funnel plot inspection [28], the Egger regression test [29], and the Duval–Tweedie trim-and-fill procedure [30]; both uncorrected and bias-corrected estimates are reported.

To examine sources of heterogeneity, random-effects meta-regression was run on three moderators: publication year (centered on 2017), log-transformed sample size, and neurophysiological technique (EEG / eye-tracking / GSR / multimodal). Each moderator was tested separately in each effect pool; additionally, a combined model including both year and log(N) was estimated, yielding a total of eight meta-regression models. Given the limited number of studies per pool ($k \approx 11$) and the exploratory nature of the analyses, Bonferroni correction was judged to be overly conservative and Benjamini–Hochberg false discovery rate (FDR) control was applied as the multiple-testing correction [31,32]. Both raw p-values and FDR-corrected q-values are reported. All statistical analyses were conducted in the R environment using the metafor package [24].

Results

The final analytic pool comprises 26 studies; 22 are allocated to the primary analyses (SMD: k = 11; correlation: k = 11) and 4 to sensitivity analyses. The total number of participants in the primary pool is N = 1,130 (median n per study = 37; range 11–224). The distribution of neurophysiological techniques is as follows: EEG (k = 10), eye-tracking (k = 4), GSR (k = 3), and multimodal combinations (k = 5), with the predominance of EEG-based measures being notable. The breadth of sample sizes (11–224) indicates that study designs range from small-scale laboratory experiments to large-sample field studies. Study-level details and the effect size estimate for each study are presented in Table 1.

Table 1 - *Summary of Primary Studies Included in the Meta-Analysis*

N = 22 primary studies. Effect sizes are presented as d *for SMD and as* r *back-transformed from Fisher Z for correlation-based studies. Confidence intervals are at the 95% level.*

Author (year)	Technique / Paradigm	Key Finding and Effect
Ohme et al. (2010) [33]	EEG / Frontal asymmetry	Left frontal EEG asymmetry was found to be salient exclusively in response to emotional advertisements and to function as a diagnostic indicator of advertising effectiveness (d = 0.56 [0.10, 1.02]).
Vecchiato et al. (2011) [34]	EEG / Theta-alpha power Spectrum	Left frontal theta-alpha power density was found to be strongly and inversely associated with advertisement liking, with left alpha desynchronization being most prominent for liked advertisements (r = −0.71 [−0.92, −0.19]).
Pozharliev et al. (2015) [35]	EEG / Late positive potential (LPP)	Luxury-branded products re found to elicit higher LPP amplitude than their basic equivalents; the effect emerged only in the social presence condition (d = 0.58 [0.25, 0.92]).
Ramsøy et al. (2018) [36]	EEG / Prefrontal gamma asymmetry	Prefrontal gamma-band asymmetry was found to predict willingness to pay; the alpha band did not demonstrate the same predictive power (r = 0.69 [0.29, 0.88]).
Bialkova & van Trijp (2010) [37]	Eye-tracking / Visual search	Label size, monochromatic color arrangement, and familiar positioning were found to increase attention to nutrition labels; larger labels were detected more rapidly (d = 0.94 [0.46, 1.42]).
Atalay et al. (2012) [38]	Eye-tracking / Central gaze cascade	Products positioned centrally in a horizontal array were found to attract more visual attention and to carry a higher probability of being chosen (r = 0.19 [−0.07, 0.42]).
Kim et al. (2021) [39]	Eye-tracking / VR retail environment	In a virtual retail environment, male participants were found to fixate on media screens longer than female participants, with gender emerging as a strong moderator (d = 1.16 [0.54, 1.79]).
Ohira & Hirao (2015) [40]	GSR / Skin conductance at the moment of preference	Skin conductance responses to preferred cosmetic products were found to be higher than those to non-preferred products, and this pattern was replicated one year later (d = 0.44 [0.09, 0.80]).
Bettiga et al. (2017) [41]	GSR / Conscious–unconscious arousal	Unconscious electrodermal and conscious self-report responses were found to function as two independent forms of affective response, influencing product attitude through different pathways (r = 0.02 [−0.14, 0.18]).
Smith et al. (2019) [42]	GSR / Children's brand responses	School-age children produced higher skin conductance responses to images of their favourite branded foods than to unbranded equivalents, indicating that early brand attachment can be tracked at an implicit level (d = 0.40 [0.11, 0.69]).

Author (year)	Technique / Paradigm	Key Finding and Effect
Ramsøy et al. (2019) [43]	EEG + Eye-tracking / Travel destination	Frontal arousal and cognitive load metrics were found to predict travel destination preferences; however, neurophysiological and self-report preferences did not fully converge (*r* = 0.58 [0.29, 0.77]).
Bettiga et al. (2020) [44]	EEG + HR + GSR / Hedonic vs. functional product	Hedonic products were found to elicit stronger physiological responses than functional products, and in the hedonic condition physiological and conscious measures formed a more congruent pattern (*r* = 0.55 [0.11, 0.81]).
Garcia-Madariaga et al. (2020) [45]	EEG + GSR + ET / Visual metaphor advertisements	The overall response to advertisements containing visual metaphors was found to be positive; cognitive load was captured only by EEG, while the same pattern did not emerge for eye-tracking and GSR (*d* = 0.08 [−0.23, 0.38]).
Bettiga & Noci (2024) [46]	EEG + ECG + GSR / TV content halo effect	Arousal, attention, and memory responses to advertisements presented following high-quality television content were found to be elevated, indicating that original content produces a halo effect (*r* = 0.42 [0.19, 0.61]).
Garczarek-Bąk & Disterheft (2018) [47]	EEG + ET + fEMG + GSR / Brand decision	For fast-moving consumer goods, the frontal EEG asymmetry index emerged as the only significant neurophysiological predictor of purchase decisions among the neurophysiological measures examined (*r* = 0.21 [0.08, 0.33]).
Wang et al. (2022) [48]	EEG / Country-of-origin congruence	Incongruence between country-of-origin and brand positioning was found to increase frontal theta oscillations as a signal of cognitive conflict; purchase intention remained elevated in the congruent condition (*d* = −0.46 [−0.79, −0.13]).
Bosshard et al. (2016) [49]	EEG / LPP for liked vs. disliked brands	LPP amplitude for liked brands was found to be higher than for disliked brands, particularly in the right parietal region at approximately 1,000 ms post-stimulus (*d* = 0.63 [0.20, 1.07]).
Diao et al. (2021) [50]	EEG / Value-based preference	In binary preference tasks with large value differences, frontal theta synchronization was found to decrease, suggesting that theta oscillations reflect attentional bias toward subjective preference (*d* = 0.56 [0.13, 0.99]).
Pozharliev et al. (2022) [51]	EEG / Influencer type and argument quality	Meso-level influencer posts were found to enhance source credibility and elicit higher cognitive processing only when combined with strong argument quality (*r* = 0.20 [0.02, 0.37]).
Di Gruttola et al. (2021) [52]	EEG / Personalized message and investment	The association between frontal alpha asymmetry and investment decisions was found to emerge only in the personalized commercial message condition; it was not observed in the low-information message condition (*r* = 0.66 [0.32, 0.85]).
Castiblanco Jimenez et al. (2022) [53]	EEG / Advergame vs. television advertisement	EEG engagement metrics for advergames were found to be higher than for traditional television advertising, and elevated engagement was positively reflected in purchase intention (*d* = 0.61 [0.13, 1.08]).
Moriuchi (2021) [54]	Eye-tracking / Product review page	Fixation on components of the product review page was found to be positively associated with purchase intention, with the pattern differing between Japanese and American participants (*r* = 0.48 [0.19, 0.69]).

Note: Effect sizes were pooled in a random-effects model (see Method). SMD and Fisher Z-based* r *subsets were combined in separate analyses; sensitivity analyses are reported.

Pooled effects computed separately for the two pools using a random-effects model (REML, Knapp–Hartung correction) yielded moderate and statistically significant results. For the SMD pool, the pooled effect was d = 0.47, 95% CI [0.18, 0.75], p = .004, with high heterogeneity ($Q(10)$ = 44.68, p < .001; τ^2 = .132; I^2 = 77.3%; 95% prediction interval [−0.39, 1.32]). For the correlation pool, the pooled Fisher Z = 0.34 (back-transformed $r \approx 0.33$), 95% CI [0.07, 0.61], p = .019, with similarly high heterogeneity ($Q(10)$ = 41.09, p < .001; τ^2 = .090; I^2 = 84.1%; 95% prediction interval [−0.38, 1.06]). The high I^2 values in both pools indicate that the cross-study variability is largely attributable to genuine heterogeneity. The width of the prediction intervals signals that a future study of similar design may depart substantially from the pooled estimate. The observed high heterogeneity should not be interpreted solely as a methodological limitation but also as an indication of the complex and context-sensitive nature of neurophysiological responses in consumer research. This variability reflects differences in stimulus characteristics, experimental paradigms, and measurement protocols across studies.

Leave-one-out analyses revealed a robust pattern in both pools: the d values obtained by successive exclusion in the SMD pool ranged across [0.41, 0.54], and the Z values in the correlation pool ranged across [0.30, 0.38]. Point estimates recomputed by successively excluding each study remained within the original confidence interval. On the Baujat diagram, the Garcia-Madariaga et al. [45] study was positioned in the upper-right quadrant (high contribution to heterogeneity + high weight) for the SMD pool; no study with this profile was identified in the correlation pool. Publication bias assessment revealed asymmetry in the SMD pool (Egger z = 2.56, p = .031); the trim-and-fill procedure imputed 3 studies and reported a downward shift of approximately 0.13 points to a corrected d = 0.33 (95% CI [0.09, 0.58]). No significant asymmetry was detected in the correlation pool (Egger z = 1.44, p = .184); the trim-and-fill procedure imputed 2 studies and the corrected value was Z = 0.26 (95% CI [0.04, 0.48]). Considered jointly, the sensitivity analyses and publication bias assessments suggest that the pooled effect in the SMD pool may harbor a modest upward inflation attributable to the over-representation of small-sample studies with positive results, while the estimate in the correlation pool exhibits a comparatively more robust profile.

To examine possible sources of heterogeneity, three moderators (publication year, log-transformed sample size, and neurophysiological technique) were tested in separate random-effects meta-regressions for each pool, together with a combined year + log(N) model, yielding a total of eight meta-regression models. The smallest raw p-value across the eight models was .073 (publication year effect in the correlation pool); the smallest FDR-corrected q-value was .461. No moderator reached statistical significance after FDR correction. This result indicates that the observed heterogeneity — which, as the high I^2 values suggest, reflects genuine cross-study variability — was not systematically explained by these three pre-specified moderators. It is judged that the explanatory variables underlying heterogeneity require more refined operationalizations beyond the coarse-level categorizations tested in this meta-analysis.

Discussion

Pooled Effect

The primary finding of this meta-analysis is that neurophysiological measures exhibit a moderate positive association with consumer outcomes (pooled d = 0.47; $r \approx 0.33$). This effect was observed in parallel across two independent statistical families and maintained its robustness against sensitivity analyses. The pooled SMD d = 0.47 (95% CI [0.18, 0.75], p = .004) and the pooled Fisher Z = 0.34 (back-transformed $r \approx$ 0.33, 95% CI [0.07, 0.61], p = .019) indicate that neurophysiological activity systematically co-varies with consumer responses. Effect directions were standardized in accordance with the principle — defined in the Method section — that stronger neurophysiological responses map onto more favorable or more pronounced consumer outcomes. Nonetheless, the overall pattern is not homogeneous. In Bettiga et al. [41], no discernible association was found between unconscious (EDA) and conscious (self-report) arousal measures ($r \approx 0.02$). In the metaphor-based advertisement study by Garcia-Madariaga et al. [45], the effect pertaining to cognitive load remained sub-threshold ($d \approx 0.08$). These two studies suggest that neurophysiological measures do not consistently yield readings parallel to consumer responses under all conditions. Stimulus type, task design, and measurement context are judged to modulate effect size in a determining manner. The fact that the prediction intervals encompass negative values in both pools (SMD PI [−0.39, 1.32]; correlation PI [−0.38, 1.06]) indicates that it remains statistically possible for a future study of similar design to report a near-zero or reverse-direction effect.

Theoretical Contributions

This study advances consumer neuroscience by moving beyond isolated empirical findings and offering a structured, integrative interpretation of neurophysiological effects within a unified framework. The results suggest that neurophysiological signals do not operate as direct or universal predictors of consumer behavior, but rather as context-dependent indicators that interact with stimulus properties and cognitive processes.

In this sense, the findings support a multi-layered interpretation of consumer response, where neurophysiological measures complement rather than replace traditional self-report methods. This integrative perspective helps reconcile inconsistencies in the literature and provides a more nuanced understanding of how implicit and explicit processes jointly shape consumer decisions. Based on these findings, a Neurophysiological–Behavioral Integration perspective is proposed, in which consumer responses are understood as the outcome of interactions between implicit physiological signals and explicit cognitive evaluations. This perspective emphasizes that predictive accuracy depends on the alignment between measurement modality and the psychological construct being assessed.

Heterogeneity and Technical Specificity

Among the studies included, the distribution of neurophysiological techniques displays a marked EEG dominance: approximately half were conducted with EEG alone (k = 10), five employed multimodal designs combining EEG with eye-tracking or GSR, and eye-tracking (k = 4) and GSR (k = 3) were less frequently used in isolation. This apparent priority of EEG-based measures may be explained by the technique's relatively low cost, the analytical tradition grounded in its temporal resolution, and its established methodological heritage in consumer neuroscience literature. A similar diversity is observed on the consumer outcome side, with purchase intention, brand attitude, advertisement evaluation, and preference outcomes distributed evenly across studies. The most frequently encountered technique–outcome pairing was between EEG-based measures and outcomes of the advertisement evaluation, liking, and preference type. Although this imbalance reflects the methodological richness of the literature reviewed, it calls for careful interpretation of pool-level comparisons, as different techniques sample different neural processes and carry different measurement errors. Rather than weakening the validity of the findings, the high level of heterogeneity observed across studies highlights the necessity of moving beyond one-size-fits-all interpretations. It suggests that future research should focus on identifying context-specific moderators rather than expecting uniform effects across different experimental settings.

Technical specificity emerges as a salient theme throughout the studies reviewed. Studies based on EEG frontal asymmetry consistently indexed approach motivation and the evaluation process [52,33,34]. Prefrontal gamma asymmetry was associated with economic decision outcomes such as willingness to pay [36]. Late positive potential studies reflected brand-level evaluation and emotional processing [49], with this effect reported to be amplified under social presence conditions [35]. Eye-tracking studies characterized attentional allocation and choice patterns [38,37], while GSR/EDA-based studies positioned autonomic arousal as a marker of consumer preference [41,40]. Reverse-direction pairings were also reported in some studies; Wang et al. [48] found that frontal theta was elevated in the incongruent (non-preferred) condition, and the effect size was accordingly given a negative sign in the table by virtue of the standardization rule. The fact that the measurement parameters employed within each technique (EEG frequency bands, eye-tracking metrics, GSR normalization procedures) differ across studies unavoidably renders pool-level pooling noisier. When examined, it is evident that this methodological diversity directly reverberates in pool-level variance. The high heterogeneity in both pools (I^2 = 77.3%–84.1%) — which is judged to originate from genuine cross-study variability rather than sampling error — when read together with the null pattern in which none of the three pre-specified moderators reached significance after FDR correction across the eight meta-regression models (smallest raw p = .073; smallest q = .461), reveals the necessity of seeking the sources of heterogeneity beyond the coarse categorizations currently available. It is suggested that the contextual details of stimuli, the cultural and demographic profile of the participant sample, the ecological validity of the experimental paradigm, and the statistical assumptions underlying effect size derivation constitute the primary sources of the observed heterogeneity. The limited number of studies per pool (k = 11) additionally constrains meta-regression power and complicates definitive inferences regarding these variables.

The publication bias assessment revealed a noteworthy asymmetry between the two pools. Funnel plot asymmetry was detected in the SMD pool (Egger z = 2.56, p = .031), and the trim-and-fill procedure imputed three studies, shifting the pooled estimate from d = 0.47 to d = 0.33 (95% CI [0.09, 0.58]). No such asymmetry was observed in the correlation pool (Egger z = 1.44, p = .184); the trim-and-fill procedure imputed two studies and the corrected value was computed as Z = 0.26 (95% CI [0.04, 0.48]). This pattern suggests that small-sample studies with positive results are over-represented in the SMD pool. The fact that the bias-corrected estimate remains significant and preserves its direction supports the robustness of the principal finding. In summary, the publication bias signal is confined to the SMD pool, while the correlation pool exhibits a comparatively more robust profile.

Conclusion

The findings of this meta-analysis should be interpreted in light of several limitations. The number of studies per pool remained limited (k = 11), searches were restricted to English-language publications and the 2010–2024 window. Methodological diversity in neurophysiological measures accounted for a substantial proportion of the heterogeneity, and the publication bias signal in the SMD pool raises a caveat regarding the distribution of small-sample studies. This indicates that future studies incorporating standardized measurement protocols, broader cultural sampling pools, and stimulus-level moderator coding (e.g., brand familiarity, stimulus duration, presentation modality) will enable a more fine-grained examination of the patterns identified in this meta-analysis. Although the number of studies included in each pool was relatively limited, this constraint also reflects the emerging nature of quantitative synthesis in consumer neuroscience. As the field matures, future meta-analyses will be able to build on a larger and more methodologically standardized empirical base.

In conclusion, this meta-analysis demonstrates that neurophysiological methods offer an additional measurement plane in consumer behavior research that runs parallel to traditional self-report measures. Pooled effect sizes were moderate, heterogeneity was high, and moderator explanatory power was limited. Nonetheless, the positive direction preserved even after bias correction signals that neurophysiological measurement makes an empirical contribution to consumer neuroscience. Future studies that test this pattern at a finer resolution with standardized protocols and broader sample pools will advance the field's theoretical integration. Overall, the findings indicate that neurophysiological methods provide meaningful but context-dependent insights into consumer behavior, reinforcing the need for integrative and multi-method research approaches in future studies.

Patient informed consent

There is no need for patient informed consent.

Ethics committee approval

There is no need for ethics committee approval.

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Author contributions subject and rate:

Candan Pamfili (40%): Primary conceptualization and development of the research, study design, systematic literature search and screening, data extraction and coding, methodological framework, interpretation of the results, preparation of the original draft, and overall coordination of the manuscript.

Selami Varol Ülker (40%): Academic supervision, methodological guidance, contribution to the interpretation of findings, critical review of the intellectual content, and review and editing of the manuscript.

Bora Karakoç (20%): Statistical analysis and statistical validation, including effect-size estimation, meta-analytic modelling, heterogeneity and sensitivity analyses, publication-bias assessment, and support in the interpretation of statistical findings.

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