



Multimodal Neuromarketing for Advertising Effectiveness Evaluation: Research Progress and Future Directions

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Abstract

With the development of consumer neuroscience, multimodal neuromarketing has increasingly been applied to advertising effectiveness evaluation. This review examines electroencephalography (EEG), functional magnetic resonance imaging (fMRI), eye tracking (ET), galvanic skin response (GSR), and facial electromyography (fEMG), focusing on what each measure contributes to the assessment of advertising responses and how their combination can extend conventional evaluation. Rather than treating multimodality as a simple aggregation of devices, the review considers its value in terms of measurement complementarity, cross-modal evidence convergence, and multimodal data fusion. Evidence from advertising and related consumer-response research suggests that these approaches can connect visual attention, neural processing, physiological arousal, affective responses, memory, and consumer choice. Applications and related evidence span audiovisual advertising, influencer marketing, online advertising, and consumer choice prediction. However, the evidence remains heterogeneous, and the interpretive limits of individual measures continue to matter. Ecological validity, small samples, high-dimensional data, model generalizability, and neurodata governance are therefore important concerns. Future research should emphasize theoretically guided multimodal designs, naturalistic stimuli, independent validation, artificial intelligence, and responsible data use. Overall, multimodal neuromarketing is best understood as a complementary framework that can enrich advertising research when different measures are selected and interpreted in relation to a common theoretical question.

Subject Areas

Neuromarketing

Keywords

Multimodal Neuromarketing, Consumer Neuroscience, Advertising Effectiveness Evaluation, Cross-Modal Evidence Convergence, Neuroforecasting

1. Introduction

Advertising effectiveness evaluation is a central concern in marketing research because advertisers need to understand whether communication captures attention, supports information processing and memory, and contributes to subsequent consumer responses [1]. In this review, advertising effectiveness refers to the extent to which an advertisement generates responses relevant to its communication and marketing objectives. These responses can emerge at different stages of consumer processing, from proximal responses such as attention, engagement, and physiological arousal to more distal outcomes such as memory, attitudes, choice, and market response. Proximal responses provide evidence about how an advertisement is processed, whereas distal outcomes more directly reflect downstream consequences. The distinction matters because different measurement approaches are better suited to different stages of advertising effectiveness. Surveys, interviews, and behavioral measures remain indispensable for assessing explicit evaluations and observable outcomes. Yet these approaches are often retrospective and may not fully capture rapid changes in attention, affect, and cognition during exposure to an advertisement. Consumer neuroscience has consequently emerged as a complementary, process-oriented approach to examining how marketing stimuli are experienced and evaluated [1] [2].

The growing use of EEG, fMRI, ET, GSR, and fEMG reflects this broader methodological shift [3] [4]. Here, multimodal neuromarketing refers to the collection and joint analysis of two or more measurement modalities from the same participants within a common experimental design. This usage is narrower than methodological triangulation, which may integrate evidence across different studies, samples, or measurement approaches [5]; the latter is therefore treated as a broader strategy for evaluating the consistency of evidence rather than as a form of multimodal measurement itself. The five modalities considered in this review were selected because, taken together, they capture complementary dimensions of consumer response: EEG is particularly informative about the temporal dynamics of neural processing, fMRI provides relatively detailed spatial information, ET indexes visual attention, GSR captures autonomic arousal, and fEMG provides information about expressive aspects of affect [4] [6]-[8]. Other measures, including ECG, respiration, and pupillometry, also have value in consumer research, but are not considered here because they fall outside the specific combination of neural, visual, autonomic, and facial-response measures examined in this review. Importantly, these modalities differ not only in what they measure but also in how

their signals can be interpreted. None, therefore, provides a complete or uniquely interpretable account of an advertising response: a fixation does not necessarily indicate liking, heightened arousal does not identify valence, and a neural signal cannot be translated directly into a single psychological state [5] [6].

This measurement heterogeneity provides the starting point for multimodal neuromarketing. Its contribution lies less in adding indicators than in combining measures that observe different aspects of the same consumer response. EEG and ET, for example, can relate visual attention to temporally aligned neural activity, while physiological and behavioral measures can connect these processes with later evaluations and choices [5] [9]. Research has also begun to move from methodological combination toward prediction, including multimodal approaches that integrate EEG and ET to classify consumer choice [10].

Against this background, the review examines multimodal neuromarketing through four closely connected perspectives. It considers the measurement capabilities and inferential boundaries of the main techniques used in advertising research, the ways in which multimodal evidence can become complementary and convergent, the integration of heterogeneous signals, and the empirical insights that have emerged around attention, emotional engagement, preference, and advertising effectiveness. Methodological and ethical challenges are considered in the final part, with particular attention to ecological validity and generalizability [9] [11], alongside emerging issues related to artificial intelligence and neurodata governance.

2. Capabilities and Boundaries of Consumer Neuroscience Measures

The usefulness of a consumer neuroscience measure depends on the question it is intended to answer. Across advertising studies, central neural, peripheral physiological, and behavioral measures contribute different kinds of information. Their value is therefore better understood in relation to their respective measurement boundaries than through a simple ranking of methods [3] [4] [12].

EEG and fMRI are the principal brain-based approaches used in consumer neuroscience. EEG records electrical activity at the scalp with high temporal resolution, making it particularly useful when researchers need to identify rapid changes in neural processing during an unfolding advertisement [2] [12]. Time-frequency measures and event-related potentials can further characterize the timing and dynamics of processing. By contrast, fMRI measures hemodynamic changes with relatively high spatial resolution and can be used to examine brain regions and networks involved in valuation, emotion, memory, and decision-making [1] [13]. The two methods thus offer complementary temporal and spatial perspectives. Their practical differences are also consequential: fMRI is more expensive and less compatible with naturalistic or prolonged advertising exposure, whereas EEG remains susceptible to artifacts and offers more limited spatial localization [2] [3].

ET and GSR capture different aspects of consumer responses outside the central

nervous system. ET provides a direct record of gaze allocation, allowing researchers to identify which advertising elements attract attention, how long they are viewed, and how visual exploration changes over the course of an advertisement [6]. Its interpretive value is nevertheless conditional. A long fixation may reflect interest, salience, complexity, or processing difficulty, while a rapid shift of gaze may indicate either low relevance or successful visual search. GSR provides a continuous index of skin conductance related to sympathetic arousal and is particularly useful for tracing physiological fluctuations during dynamic stimuli. It does not, however, indicate the valence of the elicited emotion on its own [4] [8].

fEMG provides a complementary route to affective measurement by recording electrical activity associated with facial muscles. In advertising research, facial-muscle responses can capture expressive components of affect that may not be apparent in self-reports. Lajante *et al.* [7], for example, found that the expressive component of aesthetic emotion measured with fEMG was related to attitudes toward advertisements. Related evidence from facial-expression analysis also provides support for using facial responses to evaluate emotional effectiveness in advertising [14]. Such measures can therefore complement self-report and other physiological signals, although their interpretation depends on the expressive and contextual nature of the emotional responses elicited by the stimulus [7].

Taken together, the major measures span several dimensions of advertising processing, including temporal neural dynamics, spatial neural information, visual attention, autonomic arousal, and expressive responses. These dimensions are not interchangeable: a method that is informative about one stage of processing may remain ambiguous about another. Rather than being only a limitation, this heterogeneity also creates the rationale for combining evidence across modalities. A multimodal design becomes meaningful when each measure has a clear analytical role within the same theoretical and experimental framework [3] [5] [9].

3. Multimodal Synergy in Advertising Research

3.1. Measurement Complementarity

The case for multimodal neuromarketing rests on a simple observation: consumer responses to advertising unfold across several levels, whereas individual techniques observe only part of that process. EEG can capture fast changes in neural activity, ET can locate visual attention, GSR can reveal changes in autonomic arousal, and fEMG can provide additional information about expressive responses. When these measures are synchronized around the same stimulus, they allow researchers to examine how different components of a response unfold over time rather than forcing the entire process into a single indicator [5] [9].

This approach is particularly useful for dynamic advertising. A video advertisement may combine rapidly changing images, speech, music, narrative events, and brand information. ET can identify moments when the viewer looks toward a brand or product, while EEG can characterize neural changes within the corresponding time window. GSR can further indicate whether the event is accompa-

nied by heightened autonomic activation. These measures do not answer the same question, but their combination can help distinguish exposure, attention, neural processing, and physiological activation [2] [6] [9].

Complementarity can also extend to psychometric and behavioral measures. Self-reported attitudes, memory tests, preference measures, and behavioral choices can serve as downstream outcomes against which neurophysiological responses are interpreted. This matters because advertising effectiveness is ultimately a marketing question, not only a measurement question. A useful multimodal design should therefore connect the immediate processing of a stimulus with outcomes that matter to consumers and firms [1] [5].

The choice of modalities should be guided by the research objective. Studies concerned with the timing of processing may place greater emphasis on EEG; studies focused on spatial valuation may benefit from fMRI; research on attention to specific advertising elements naturally prioritizes ET; and studies concerned with arousal or expressive responses may add GSR or fEMG. The review by Quiles Pérez *et al.* [9] similarly shows that biosignal combinations in neuromarketing reflect differences in research objectives, stimuli, and analytical procedures. Multimodality is therefore most useful when measures are selected for complementary purposes rather than simply because additional data are available.

3.2. Cross-Modal Evidence Convergence

Complementary measures do not need to produce identical results. Differences between modalities can be informative because each signal reflects a different aspect of the consumer response. High visual attention may occur without strong autonomic activation, for example, whereas a stimulus may generate pronounced arousal without sustained fixation. Treating such divergence as measurement failure would overlook the possibility that attention and arousal occur at different stages or with different intensities.

A more useful perspective is to ask whether evidence from different measures converges around a common advertising event. Suppose a brand element receives sustained fixation, is accompanied by a change in EEG activity, and is followed by greater recognition or preference. No single indicator establishes the full interpretation, but the combined pattern provides stronger process-level evidence than any one measure considered alone. Data triangulation offers a related methodological principle: neurophysiological, psychometric, and behavioral evidence can be brought together to examine the same research question [5].

This approach also offers a cautious response to reverse inference. A physiological or neural signal rarely has a one-to-one relationship with a psychological state. The same response may arise from different processes, and different measures may be influenced by task demands that are not central to the focal construct. Cross-modal convergence can narrow interpretive ambiguity, but it does not eliminate it [5] [7]. Multimodal evidence is therefore better used to build an evidence chain than to assign definitive psychological labels to isolated biomarkers.

Evidence convergence has both empirical and theoretical dimensions. Researchers need to specify what each modality is expected to contribute and why the resulting pattern would be relevant to the proposed mechanism. When this logic is explicit, agreement across measures can strengthen an interpretation, whereas disagreement can prompt closer examination of timing, task demands, or stimulus characteristics. Multimodal research thus creates value not only through additional data, but also through a more differentiated account of consumer responses [5] [9].

3.3. Multimodal Data Fusion and Prediction

Once multiple signals are collected, the central challenge is to integrate information that differs in temporal dynamics, measurement properties, and analytical form. Multimodal data can be integrated at the signal, feature, or decision level. Signal-level fusion focuses on synchronization and preprocessing, feature-level fusion combines theoretically meaningful variables extracted from different modalities, and decision-level fusion integrates the outputs of separately trained models [9]. The choice among these approaches should follow the research question and the nature of the available data. In particular, synchronization requires more than matching timestamps across modalities. EEG and ET measures can be closely related to the timing of stimulus events, whereas GSR and fMRI involve slower physiological and hemodynamic responses. Analyses should therefore allow for modality-specific response latencies when defining event windows and relating signals to a common advertising event. Without such temporal considerations, apparently synchronized measures may reflect different stages of the underlying response process.

Feature-level fusion has attracted particular attention because it allows complementary information from different modalities to be represented within a common predictive framework. Usman *et al.* [10], for example, combined EEG and ET to predict buy versus non-buy decisions using data from 42 participants in the NeuMa dataset. Their proposed model achieved 84.01% accuracy under stratified 10-fold cross-validation, compared with 80% for the strongest listed EEG-ET comparison model and 62% for an EEG-only baseline using raw data, machine-learning features, and SVM. The results provide evidence that combining neural and visual information can improve choice prediction within the dataset, while the validation design and limited sample size constrain broader claims about generalizability. Related work has likewise examined the predictive value of combining EEG with other consumer-response measures, suggesting that multimodal prediction is becoming an important extension of single-modality approaches [15].

Prediction should nevertheless be distinguished from explanation. A model may classify consumers accurately without providing a clear account of the psychological mechanism linking the stimulus to the outcome. Multimodal fusion also increases data dimensionality and can amplify the risk of overfitting when sample sizes are modest [9] [15]. A more complex model may exploit information

that improves prediction within a dataset while becoming less transparent or less stable across samples.

The predictive question also exists at different levels. Individual-level models attempt to predict a particular consumer's choice, whereas neuroforecasting asks whether neural responses can predict aggregate consumer behavior or market outcomes. Yao and Wang [16] emphasize that aggregate forecasting raises additional questions about sample size, ecological validity, cost, and generalizability. Multimodal fusion may support this transition, but the practical value of a model depends on whether its predictive relationship remains stable beyond the original experimental sample [16].

4. Empirical Applications and Insights in Advertising Research

4.1. Attention and Visual Processing

Attention is one of the most established targets of consumer neuroscience because advertising effectiveness often depends on whether consumers notice relevant information in the first place. ET studies show that visual attention reflects both stimulus-driven properties, such as salience and spatial prominence, and goal-driven influences, including the viewer's task and objectives [6]. Attention is therefore shaped not only by visual design, but also by the relationship between the stimulus and the consumer's current processing context.

Multimodal evidence makes this distinction more concrete in digital and social-media advertising. Pozharliev *et al.* [17] simultaneously recorded EEG and ET responses from 109 participants viewing Instagram influencer advertising. Under weak argument quality, product-use photos of micro-influencers received more visual attention than the corresponding photos of meso-influencers. Attention also mediated the joint effect of influencer type and argument quality on behavioral activation. This design is particularly informative because it links a specific visual element to gaze behavior and a neurophysiological measure within the same experimental design, showing how source characteristics and message quality can shape both where consumers look and how strongly they respond [17].

The timing of commercial disclosures provides another example. Van Reijmersdal *et al.* [18] found that sponsorship disclosures presented before an influencer video attracted more visual attention than disclosures shown at the start of the video among early adolescents. Earlier disclosure also improved recognition of the sponsored nature of the content and produced more critical attitudes toward the sponsored material. The finding illustrates why the timing of an advertising element matters: the same information may have different processing consequences depending on when it enters the viewer's field of attention [18].

Research combining EEG, ET, and fMRI likewise shows how advertising cues can be examined at multiple levels [19]. Rather than treating an advertising cue simply as "noticed" or "ignored", such designs allow researchers to consider visual attention alongside neural processing and preference formation. The empirical

contribution of multimodal research, therefore, is not merely to measure attention more extensively, but to examine how attention fits into a broader sequence of consumer responses.

These findings also clarify what multimodality cannot establish by itself. Greater fixation does not automatically imply stronger preference, and a visually prominent element may require additional processing precisely because it is complex or unfamiliar. Multimodal evidence becomes more informative when gaze is interpreted alongside neural, physiological, and behavioral measures rather than treated as a direct proxy for advertising effectiveness [5] [6].

4.2. Emotional Engagement and Advertising Content

Emotion is another major target of advertising research because advertisements often seek not only to attract attention but also to elicit affective responses that can shape attitudes, memory, and subsequent behavior. Yet emotional engagement cannot be reduced to a single physiological indicator. Eijlers *et al.* [20] found that neural arousal was positively associated with advertisement notability but could be negatively associated with advertising attitudes. This finding illustrates that arousal and favorable evaluation represent related but distinct dimensions of advertising response: an advertisement may elicit strong physiological arousal without producing a positive attitude.

Affective responses can also be expressed through different channels. Lajante *et al.* [7] examined aesthetic emotions elicited by commercials and found that the expressive component measured with fEMG was associated with attitudes toward the advertisements, alongside subjective emotional responses. Their findings indicate that facial-muscle activity can provide information about advertising experience that is not identical to self-report, while also illustrating the value of distinguishing expressive and subjective components of affect [7].

Advertising content may further shape emotional engagement through interactions across sensory channels. Peng-Li *et al.* [21] examined how taste-congruent soundtracks influenced visual attention to food items and found that sweet music increased fixation on sweet foods, whereas salty music increased fixation on salty foods; these patterns were also related to food choice among Chinese and Danish participants. The findings provide supporting evidence that cross-modal sensory congruence can shape visual attention and subsequent choice, offering a useful reference for understanding similar processes in multisensory advertising.

Related evidence from social communication further illustrates the value of examining emotional responses across modalities. Zito *et al.* [8] combined EEG, skin conductance, and ET to examine emotional responses to social communication materials. Their findings demonstrate how neural, physiological, and visual measures can be integrated to characterize emotional engagement as a pattern unfolding across time and modalities rather than as a single score labelled “emotion” [8]. Although these findings arise from a different communication context, they reinforce the broader methodological point that emotional engagement is better understood through converging evidence from multiple response channels.

For advertising researchers, the implication is that emotional engagement should be considered in relation to both content characteristics and subsequent outcomes. The relevant question is not simply whether an advertisement raises arousal, but which features produce that response, how attention and affect develop across modalities, and whether the resulting response contributes to memory, attitudes, or choice. A process-oriented view therefore helps distinguish salience from favorable evaluation while avoiding the assumption that any single measure can fully explain advertising effectiveness [7] [8] [20].

4.3. Preference, Purchase-Related Responses, and Advertising Effectiveness

A further stream of research considers whether consumer neuroscience measures can connect advertising exposure with outcomes that are more directly relevant to effectiveness, including preference, memory, purchase-related responses, and market performance. Venkatraman *et al.* [13] provided an influential example by combining self-reports with ET, biometric measures, EEG, and fMRI in television advertising research. Their findings showed that neurophysiological measures could provide incremental information for predicting advertising success and market response beyond traditional measures. This work is important because it places consumer neuroscience within a broader outcome framework, linking responses during advertising exposure with downstream indicators of effectiveness [13].

At the individual level, research has increasingly examined how neural and physiological responses relate to consumer preference. Byrne *et al.* [15], in a systematic review of EEG-based neuromarketing prediction, identified frontal alpha asymmetry (FAA) and the late positive potential (LPP) as relatively consistent indicators across studies, while also highlighting substantial variation in predictive performance. The review further indicated that prediction may benefit from combining EEG with other consumer-response measures, including ET and facial-expression analysis [15]. These findings suggest that consumer preference may be better understood through converging patterns across measures than through reliance on a single biomarker. Importantly, however, improved prediction at the individual level should not be treated as equivalent to evidence of advertising effectiveness at the market level.

Beyond preference, memory provides another important link between advertising exposure and later consumer outcomes. Casado-Aranda *et al.* [22] found that hedonic banner advertisements elicited stronger neural processes related to memory encoding and retrieval than utilitarian banners, and that hedonic advertisements were better recalled in a subsequent surprise memory task. Their findings suggest that advertising appeals can influence both memory-related neural processing and observable recall, illustrating how neuroimaging evidence can help connect advertising content with downstream cognitive outcomes [22]. Yen and Chiang [19] similarly combined ET, EEG, and fMRI to examine responses to online advertising cues, demonstrating how visual, electrophysiological, and neuroimag-

ing measures can be examined together within a common advertising context.

Research has also examined how different forms of advertising content are associated with distinct neural responses. Adalarasu *et al.* [23], for example, recorded EEG responses while participants viewed television commercials representing different genres and content elements. This line of research shifts attention from a single global measure of advertising effectiveness toward the processing consequences of specific advertising executions. Taken together, these studies indicate that advertising effectiveness is multidimensional: attention and physiological responses may characterize immediate processing, whereas memory, preference, purchase-related responses, and market outcomes reflect progressively downstream consequences. Multimodal neuromarketing is therefore most informative when these outcomes are considered as related but distinct components of the broader advertising response process.

4.4. The Incremental Value of Multimodal Evidence

What, then, does multimodality add beyond the use of several measures side by side? The empirical literature points to three forms of added value. One is process resolution: different measures can locate distinct stages of an advertising response, from visual attention to neural processing and physiological activation. Another is interpretive support: converging evidence can make an explanation more credible than an inference based on a single psychologically nonspecific signal [5]. A third is predictive potential: combined features may capture patterns relevant to consumer choice or advertising response that are not fully represented in one modality [10] [15].

The practical value of these advantages depends on research design. A multimodal experiment that collects many signals without a clear theoretical purpose may generate more variables without generating more understanding. By contrast, a design that assigns different measures to different stages of processing can produce a more informative evidence chain. The 2024 data-fusion review by Quiles Pérez *et al.* [9] reflects this broader development in neuromarketing, where the selection and combination of biosignals are increasingly linked to research objectives and analytical procedures.

The evidence therefore supports a qualified conclusion. Multimodal neuromarketing can enrich advertising effectiveness evaluation when different measures answer complementary questions and are connected to meaningful behavioral outcomes. Its contribution is less convincing when multimodality is treated as an end in itself or when predictive gains are interpreted without independent validation. Research design quality consequently matters at least as much as the number of signals collected.

5. Challenges and Future Directions

5.1. Ecological Validity and Naturalistic Research

A persistent challenge is the gap between laboratory measurement and real adver-

tising exposure. Laboratory studies offer control over timing, stimulus presentation, and measurement conditions, but consumers often encounter advertisements while browsing, multitasking, interacting with others, or using mobile devices. Portable and wearable systems create opportunities to bring EEG and ET beyond highly controlled settings [2] [4] [11]. These advantages, however, also come with practical challenges: movement artifacts, calibration problems, changing light conditions, and practical constraints can reduce signal quality.

The goal is not to abandon laboratory control, but to connect controlled experiments with more naturalistic validation. Dynamic advertisements, online browsing tasks, virtual retail settings, and real product environments can complement conventional screen-based paradigms. This direction is consistent with the broader literature, which increasingly treats naturalistic stimuli and real-world consumer contexts as important for strengthening external and ecological validity [11] [12].

5.2. Small Samples, High-Dimensional Data, and Generalizability

Multimodal studies create a structural tension between data richness and sample size. A single experiment can generate large numbers of EEG features, gaze metrics, GSR responses, fEMG measures, behavioral outcomes, and questionnaire variables. When many predictors are evaluated in relatively small samples, the risk of overfitting increases, and models may fit idiosyncratic features of the observed sample rather than stable relationships.

This problem is especially relevant when machine learning is used for preference prediction or neuroforecasting. Byrne *et al.* [15] reviewed a substantial EEG literature and found considerable variation in the predictive consistency of individual indicators. Yao and Wang [16] likewise identify sample size, ecological validity, cost, and generalizability as central challenges in forecasting aggregate consumer behavior from neural data. These concerns suggest that future multimodal studies should report clear validation procedures, use independent test samples where feasible, and place greater weight on replication across products, populations, and contexts [15] [16].

Generalizability also involves individual differences. Baseline physiological activity, attentional patterns, prior product experience, age, culture, and media-use habits may influence how consumers respond to the same advertisement. A model trained within a narrow participant pool may therefore explain that sample well while remaining uncertain outside it. Cross-participant and cross-context validation should consequently become a routine part of multimodal neuromarketing research rather than an optional final step.

5.3. Artificial Intelligence, AI-Generated Content (AIGC), and Neuroforecasting

Artificial intelligence is increasingly shaping both how advertising content is produced and how consumer responses are evaluated. Generative AI can rapidly produce or modify multiple versions of advertising text and visual material, allowing

content development to move toward a more iterative process of generation, testing, and optimization. Such AI-generated content (AIGC) introduces a new dimension to advertising research because the source and production process of an advertisement may themselves become part of the consumer response. Chen *et al.* [24] found that consumers responded more positively to AI-generated advertisements using agentic appeals, whereas human-created advertisements performed better for communal appeals. This finding suggests that responses to AI-generated advertising depend not simply on whether AI is involved, but on how the use of AI interacts with the advertising appeal and the perceived role of the content creator [24].

For multimodal neuromarketing, this development creates an opportunity to connect content generation with consumer-response measurement. Rather than evaluating only a limited set of finished advertisements, future studies could compare multiple AI-generated and human-created executions while recording neural, visual, physiological, and behavioral responses. Such designs could help identify which features of generated content are associated with attention, arousal, affective engagement, memory, or preference, and could provide evidence for subsequent content refinement. In this sense, generative AI may enable a more iterative generation-measurement-learning-optimization process, although the empirical basis for such closed-loop applications remains limited.

AI may also facilitate multimodal neuroforecasting by handling heterogeneous data and identifying nonlinear relationships across modalities. However, greater computational flexibility does not by itself establish stronger advertising effectiveness. Future research should therefore evaluate predictive performance alongside interpretability, generalizability, and incremental value relative to established consumer measures [10] [11] [16].

5.4. Neuroethics and Neurodata Governance

The expanding integration of neural, physiological, behavioral, demographic, and consumption data raises ethical questions that differ in scale from those associated with a single questionnaire or one physiological measure. Multimodal datasets can increase the information available for inferring preferences and behavioral tendencies, making privacy, autonomy, informed consent, and potential misuse increasingly relevant [25].

Informed consent should therefore cover not only data collection but also storage, sharing, secondary use, and algorithmic processing. When data are used to train machine-learning models or optimize advertising content, participants should be informed about the intended uses and relevant access conditions. Researchers should also maintain a clear distinction between what is directly measured and what is inferred from those measurements. Ferrell *et al.* [25] emphasize the continuing ethical debate surrounding privacy, scientific validity, autonomy, and the potential manipulation of consumers.

Responsible neuromarketing also requires restraint in how findings are com-

municated. Neural and physiological measures provide context-dependent and probabilistic evidence; they do not amount to direct mind reading or deterministic prediction of individual purchase decisions. Clear reporting of measurement limitations, data governance, and uncertainty is therefore part of methodological quality rather than a separate ethical add-on [5] [25].

6. Conclusions

Multimodal neuromarketing provides a useful framework for advertising effectiveness evaluation because it allows researchers to combine evidence from different stages of consumer processing. EEG, fMRI, ET, GSR, and fEMG do not measure the same construct, and their value lies precisely in the different information they contribute. When selected according to a common theoretical question, these measures can connect visual attention, neural dynamics, physiological activation, affective response, memory, and consumer choice.

Empirical research has demonstrated the usefulness of this approach across influencer advertising, audiovisual communication, online advertising, affective responses, and consumer choice prediction. The evidence nevertheless remains context dependent. More data do not automatically produce more convincing explanations, and predictive performance does not by itself establish a psychological mechanism or market-level validity.

Future research should focus on theoretically guided multimodal design, naturalistic validation, stronger out-of-sample testing, and more transparent use of artificial intelligence. Equally important, the field needs governance practices that protect privacy and consumer autonomy as the capacity to combine and infer from neurodata increases. Multimodal neuromarketing is most valuable not as a replacement for conventional advertising research, but as a complementary means of linking advertising stimuli to the processes and outcomes through which effectiveness emerges.

Author Contributions

Yaqi Yang: Literature search and synthesis, writing—original draft, and writing—review and editing. Zhiwei Xu: Supervision and critical review of the manuscript. Both authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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