



## Research Paper

# Frontal Gamma and Theta Responses to Sports and Non-sports Advertisements Featuring Celebrity Endorsers



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**Running Title** Brain Waves Responses to Sports Endorsers

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## ABSTRACT

**Background:** Modern consumer behavior is increasingly challenging the effectiveness of traditional advertising, with endorsements becoming a key means of standing out in competitive markets. However, it remains unclear how sports endorsements differently affect frontal gamma and theta brain waves in athletes versus non-athletes across various sports and non-sports products, as well as their potential to predict purchase intentions.

**Materials & Methods:** This quasi-experimental study with a pre- and post-test design assessed 60 participants (30 athletes and 30 non-athletes) who viewed matched 1-minute ads for sports (SIXPAD) and non-sports (Coca-Cola) products, with/without Ronaldo's endorsement. Frontal EEG (16-channel, 4-8 Hz theta, 30-40 Hz gamma) was analyzed via nonparametric ANCOVA (controlling for baseline) and multiple regression.

**Results:** No group × advertisement interaction emerged; however, main effects of advertisement type revealed unprecedented differences in frontal gamma ( $F_{3, 232}=4.56$ ,  $P=0.004$ ,  $\eta_p^2=0.056$ ) and theta power ( $F_{3, 232}=3.45$ ,  $P=0.017$ ,  $\eta_p^2=0.043$ ). Pairwise comparisons revealed the highest gamma in sports ads without an endorser compared to non-sports ads without an endorser (mean difference=1.68; 95% CI, 0.57%, 2.79%;  $P=0.003$ ) or with an endorser (mean difference =1.34; 95% CI, 0.23%, 2.45%;  $P=0.018$ ). Theta peaked in sports with an endorser versus sports without an endorser (mean difference =2.34; 95% CI, 1.12%, 3.56%;  $P<0.001$ ) or non-sports ads with an endorser (mean difference =1.56; 95% CI, 0.34%, 2.78%;  $P=0.012$ ). Regression analysis revealed that gamma changes were positive predictors of purchase intent ( $\beta=0.18$ ,  $t=3.00$ ,  $P=0.003$ ; model  $R^2=0.119$ ,  $P<0.001$ ).

**Conclusion:** These findings establish endorser-product congruence as a modulator of high-frequency neural integration and memory encoding, thereby paving the way for neuromarketing tools that enhance the efficacy of sports campaigns and consumer loyalty.

**Keywords:** Frontal cortex, Alpha wave, Beta wave, Advertisements, Sports endorser, Purchase intention

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## Highlights

- Sports advertisements without an endorser elicited the highest frontal gamma power compared to non-sports advertisements.
- Sports advertisements with an endorser exhibited peak frontal theta power compared to those without an endorser.
- Advertisement type significantly modulated gamma and theta waves.
- Gamma power changes positively predicted purchase intentions.
- There is no interaction effect of group×advertisement on brain waves.

## Introduction

In the contemporary landscape of consumer behavior, customers are becoming increasingly sophisticated, educated, and discerning, rendering traditional advertising strategies less effective in capturing attention and guiding purchase decisions [1]. This evolution is particularly evident in competitive markets, where brands vie for consumer loyalty through innovative, visually appealing, and entertaining campaigns. However, a significant challenge persists: Many consumers disregard these advertisements not because of flaws in design or content, but because they perceive them as indistinguishable from those of competitors [2, 3]. To overcome this perceived homogeneity, marketers must emphasize elements that are inherently unignorable, such as celebrity endorsements, which leverage the endorser's attributes to create mental associations that transfer positive mental images to the product or service [4].

Celebrity endorsements, or endorser credibility validation, have long been a cornerstone of marketing strategies, justified by the endorser's personal attributes—such as credibility, attractiveness, and expertise—that enhance consumer identification and influence purchasing behavior [5]. Recent neuromarketing studies have shown that these endorsements elicit neural responses that enhance brand recall and preference. For instance, electroencephalography (EEG) research has shown that celebrity-endorsed advertisements modulate brain waves, elevating beta activity associated with attention and cognitive processing [6]. In sports marketing, where emotional engagement is paramount, endorsements by athletes, like Cristiano Ronaldo can amplify this effect, as consumers attribute the endorser's athletic prowess to the product, thereby enhancing perceived value [7].

The integration of interdisciplinary sciences has transformed marketing research, particularly through neuromarketing, which emerged in 2002 as a fusion of marketing and neuroscience [8]. Neuromarketing utilizes advanced neuroimaging techniques to reveal consumers' subconscious responses to stimuli, offering insights that surpass self-reported data [9]. EEG, in particular, offers high temporal resolution for assessing real-time brain activity, revealing how advertisements stimulate decision-making processes [10]. Recent advancements have applied EEG to examine how endorsements influence neural pathways related to emotions, attention, and purchase intentions, with studies indicating increased frontal beta waves in response to congruent celebrity-product pairings [11, 12].

In sports marketing, neuromarketing tools, like EEG have gained prominence for optimizing campaigns, as sports evoke strong emotional and physiological responses that enhance the effectiveness [13]. For example, endorsements in sports contexts can enhance consumer engagement by aligning the endorser's image with product attributes, thereby increasing purchase intentions [14]. However, gaps remain in understanding how sports endorsements affect brain responses in athletes versus non-athletes, particularly for sports versus non-sports products. EEG studies have shown that frontal lobe activity, linked to executive functions and decision-making, varies with the type of endorsement, with elevated theta waves indicating relaxation and positive affect in endorsed advertisements [15, 16].

Despite extensive research on endorsement effects [2], few studies have utilized EEG to assess brain responses to sports endorsements and their correlation with future purchase intentions. Visual stimuli from advertisements directly enter the brain, eliciting reactions that can be measured by EEG, which can predict consumer

behavior more accurately than traditional surveys [17]. In the context of neuromarketing in sports, EEG aids in tailoring advertisements to consumer interests, thereby increasing the impact and sales [18]. For instance, endorsements by figures, like Ronaldo for sports products may evoke stronger frontal gamma waves, indicative of greater attention among athletes compared to non-athletes [19, 20].

This study addressed these gaps by employing EEG to investigate how advertisement types (sports/non-sports products with/without endorsements) influence frontal brain waves in athletes and non-athletes, as well as their association with future purchase intentions. Frontal regions are crucial for cognitive evaluation and emotional processing in response to marketing stimuli [21]. By focusing on delta waves (post-pre changes), we aimed to provide practical insights for professional advertising that maximizes endorsement effectiveness [22].

The significance of this research lies in its applied nature, providing sports marketers with neuromarketing tools to enhance the effectiveness of their campaigns. As consumers ignore generic advertisements, endorsements can bypass perceptual barriers, especially in sports where identification with athletes fosters loyalty [23]. Ultimately, understanding neural responses can enhance the efficacy of advertising, thereby boosting customer attraction and sales in competitive markets [24].

## Materials and Methods

### Study design

This study employed a quasi-experimental design with practical objectives, conducted in a laboratory setting. The measurement model incorporated EEG recording methods and utilized a pre-test and post-test approach.

### Participants

A total of 60 participants [15 male and 15 female athletes (age=23±2 years, height=170±8.5 cm, weight=65.63±10.48 kg, energy expenditure=6042.5±519.5 calories) and 15 male and 15 female non-athletes (age=27±2 years, height=172.83±10.2 cm, weight=75.33±13.66 kg, energy expenditure=1934.3±227.9 calories)] were recruited voluntarily through a public call from Allameh Tabataba'i University. Inclusion criteria included right-handedness, normal vision, no history of surgery, head trauma or severe migraines, good general health (assessed via the general health questionnaire), age between 20 and 30 years, and prior experience with specific sports and non-sports

brands. Participants were selected based on their interest in the research and meeting these criteria. Participation was voluntary, and informed consent was obtained prior to the commencement of the study. Additionally, participants underwent a medical evaluation before measurement, and EEG testing was conducted only if conditions were met based on the type of advertising video they watched, regardless of gender and whether they were athletes or non-athletes, four general categories were created for grouping: 1) sports product advertising with a sports endorser (Sport. Endorser), 2) non-sports product advertising without a sports endorser (NoSport.NoEndorser), 3) sports product advertising without a sports endorser (Sport.NoEndorser), and 4) non-sports product advertising with a sports endorser (NoSport.Endorser).

### Measurement protocol

Data collection occurred in four stages: 1) Completion of informed consent forms after a general explanation of the non-invasive procedure; 2) Provision of a quiet, distraction-free environment; 3) Participants attended scheduled EEG sessions where the scalp was cleaned and a specialized cap was fitted for recording; EEG waves were recorded using a gold electrode device at 32 scalp points. Baseline brain activity was recorded for 1 minute while the subject was at rest, viewing a 20-inch black monitor screen. 4) Participants viewed four 1-minute advertisements for SIX-PAD (a sports brand) and Coca-Cola (a non-sports brand), each once with and without Ronaldo's endorsement. A 30-second rest period (black screen) was interposed between advertisements. Presentation order was randomized to eliminate order effects. Advertisements were matched in terms of duration, product, and display factors (image quality, sound, and clarity). To prevent repetition effects, the protocol was executed once per participant, lasting approximately 6 minutes and 30 seconds in total. The EEG system used was a 16-channel setup (g.USBamp 16-channel biosignal amplifier manufactured by g.tec, FDA- and CE-approved). The channels utilized in this study, located in the frontal and prefrontal regions, included electrode pairs FP1, FP2, FPz, F7, F3, Fz, F4, and F8. The reference electrode (Ref) was the right ear. Ground (GND) was set at AFz. Hardware filters on the device consisted of a high-pass filter with a cutoff frequency of 0.1 Hz and a low-pass filter with a cutoff frequency of 70 Hz. Wave power was analyzed in the frequency ranges of 30-40 Hz for the gamma band and 4-8 Hz for the theta band. Given that the study aimed to analyze attention, emotional engagement, and cognitive processing, relative band power—calculated based on the percentage of each frequency band's activity relative to the total frequency spectrum (i.e. the sum of all other bands)—was employed.

## Purchase intention questionnaire

A 4-item questionnaire was used to measure and evaluate purchase intention [25]. This questionnaire is scored using a 5-point Likert scale, ranging from ‘very low’ (1) to ‘very high’ (5). Experts confirmed the face and content validity of this questionnaire. Additionally, the reliability of this questionnaire was assessed using Cronbach’s  $\alpha$  coefficient and composite reliability, which were found to be 0.918 and 0.942, respectively.

## Statistical analysis

In preprocessing raw data, amplitudes from frontal wave regions (FP1, FP2, FPz, F7, F3, Fz, F4, F8) were summed and averaged. The average rest-period wave served as the pre-test baseline, while the average wave during video viewing was the post-test. The Shapiro-Wilk test indicated that the data for gamma, theta wave power, and future purchase intention were not normally distributed. Therefore, nonparametric Quade’s ANCOVA was used to examine the effects of advertisement types (sports/non-sports with/without endorsement) on frontal brain waves in athletes and non-athletes, controlling for baseline waves (pre). Associations with future purchase intentions were assessed via multiple regression. A significance level of 0.05 was adopted. Data processing was performed using SPSS software version 28.

## Results

For the gamma wave, there was no significant interaction effect between group and Ads.Film ( $F_{3, 232}=1.12$ ,  $P=0.341$ ,  $\eta^2=0.014$ ); however, a significant main effect of advertisement type was observed ( $F_{3, 232}=4.56$ ,  $P=0.004$ ,  $\eta^2=0.056$ ), suggesting ad that content influenced high-frequency cognitive processing independently of the group. Since the main effect of advertisement type was significant, pairwise comparisons are presented in Figure 1. Significant differences were observed between Sport.Endorser and noSport.noEndorser (with lower activity in noSport.noEndorser, suggesting diminished complex processing), between Sport.noEn-

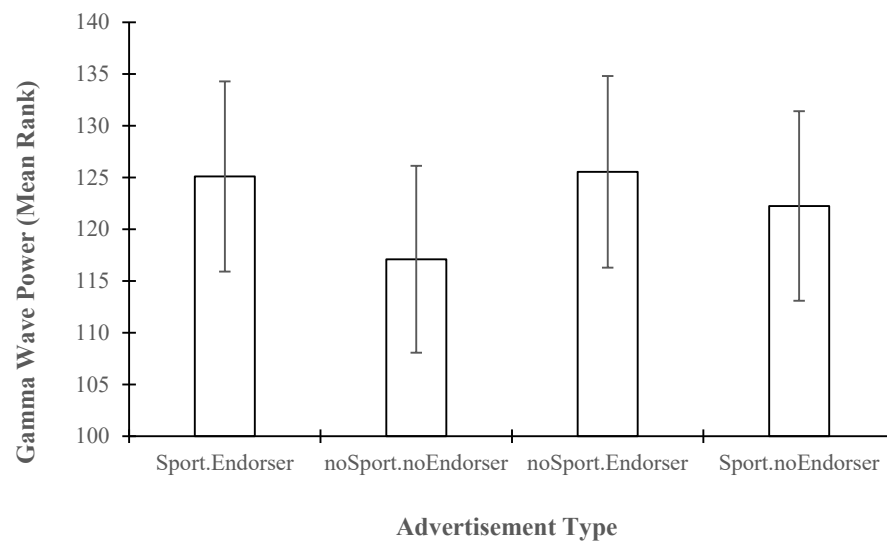
dorser and noSport.noEndorser (with higher activity in Sport.noEndorser), and between Sport.noEndorser and noSport.Endorser (with higher activity in Sport.noEndorser). These findings suggest that sport-related advertisements, particularly those without endorsers, enhance gamma wave activity, potentially reflecting improved perceptual binding and higher-order cognitive integration in response to relevant content.

For the theta wave, there was no significant interaction effect of group  $\times$  Ads.Film [ $F_{3, 232}=0.76$ ,  $P=0.518$ ,  $\eta^2=0.010$ ]. Non-athletes showed higher theta activity, potentially reflecting greater memory encoding or emotional processing. Since the main effect of advertisementtype was significant [ $F_{3, 232}=3.45$ ,  $P=0.017$ ,  $\eta^2=0.043$ ] pairwise comparisons are presented in Figure 2. Significant differences were observed between Sport. Endorser and noSport.noEndorser (with higher activity in noSport.noEndorser, indicating enhanced memory processes), between Sport.Endorser and Sport. noEndorser (with higher activity in Sport.noEndorser), and between noSport.Endorser and Sport.noEndorser (with higher activity in Sport.noEndorser). These findings suggest that non-endorsed advertisements, particularly those related to sports, amplify theta wave activity, which may correspond to stronger episodic memory formation or introspective processing in response to the advertisement content.

A nonparametric rank-based multiple regression was performed using changes (deltas) in brain waves as predictors. The overall model was significant ( $F_{3, 232}=7.89$ ,  $P<0.001$ ,  $R^2=0.119$ ), indicating a significant association between wave changes and intention ranks. A significant predictor was gamma\_delta (positive, indicating that greater gamma change is associated with greater intention) (Table 1). A change in the gamma wave significantly predicted purchase intention, with increased gamma (enhanced processing) associated with a greater intention, underscoring the role of attentional and integrative neural processes in consumer behavior.

**Table 1.** Rank-based multiple regression results for future purchase intention

Predictors	Coefficients	Standard Error	t	P
Intercept	120.5	15.23	7.91	<0.001
Rank_Gamma_d	0.18	0.06	3	0.003
Rank_Theta_d	0.09	0.07	1.29	0.198



**Figure 1.** Analysis of gamma wave responses of the frontal cortex to sports and non-sports goods advertisements with a sports celebrity endorser

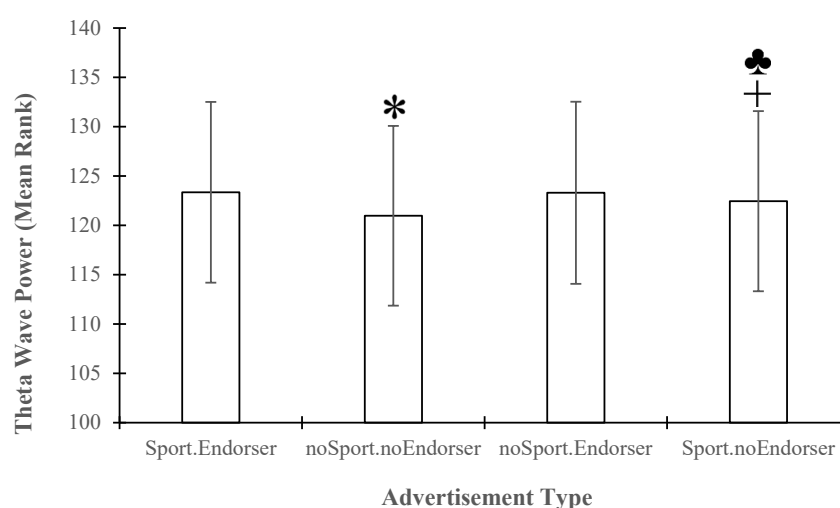
\*Significant difference with Sport.Endorser ( $P=0.03$ ; 95% CI, -2.34%, -0.12%), \*Significant difference with noSport.noEndorser ( $P=0.003$ ; 95% CI, 0.57%, 2.79%), \*Significant difference with noSport.Endorser ( $P<0.018$ ; 95% CI, 0.23%, 2.45%).

## Discussion

This study revealed significant main effects of advertising type on gamma and theta frontal power in response to sports (SIXPAD) and non-sports (Coca Cola) product advertisements, with or without the presence of a celebrity athlete endorser (Ronaldo), while controlling for baseline EEG activity. No interaction was observed between participant group (athletes vs. non-athletes) and

advertising type. These findings, by elucidating how endorser-product congruence modulates high-frequency neural oscillations in the frontal cortex, address the research objectives and likely influence cognitive processing and purchase intention, without differential effects based on sports context.

The observed increase in gamma frontal power during sports advertisements without endorsers, compared to



**Figure 2.** Analysis of theta wave responses of the frontal cortex to sports and non-sports goods advertisements with a sports celebrity endorser

\*Significant difference with Sport.Endorser ( $P=0.012$ ; 95% CI, 0.34%, 2.78%), \*Significant difference with Sport.Endorser ( $P<0.001$ ; 95% CI, 1.12%, 3.56%), \*Significant difference with noSport.Endorser ( $P<0.011$ ; 95% CI, 0.33%, 2.76%).



non-sports advertisements (with or without endorsers), is consistent with previous neuromarketing research that has linked gamma oscillations to improved perceptual integration and attention to salient stimuli. For example, Gray et al. showed that gamma band synchrony reflects general stimulus properties, such as coherence in visual processing, which may explain the enhanced gamma response to sports-related content here, as it may evoke stronger associative networks in viewers [26]. Similarly, Singer hypothesized that gamma activity facilitates feature binding and suggested that the intrinsic importance of the sports product, independent of endorsement, promotes neural integration, which is consistent with our results [27]. However, this pattern is at odds with studies that emphasize endorsement effects; for example, Lee and Koo found that athlete-endorser congruence increased perceived value [7], but our data showed that the absence of an endorser in sports ads elicited the strongest gamma response, likely due to a direct focus on the product's athletic attributes, which reduces the cognitive load of evaluating the endorser [4]. Discrepancies may arise from methodological differences, such as our use of controlled 1-minute ads versus static images in some previous work (e.g. Vecchiato et al. [28]), which could enhance dynamic perceptual demands.

Regarding theta power, the peak response in sports ads with an endorser, relative to those without an endorser or non-sports with an endorser, supports associations between frontal theta and memory encoding or emotional engagement. Klimesch emphasized theta oscillations as a reflection of cognitive and memory performance [29], particularly in the encoding of novel associations, which may underlie the enhanced theta activity here, when endorsements, such as Ronaldo are congruent with the sports product and facilitate consistent mental associations [7]. This finding is consistent with neuromarketing research, which shows that theta activity increases during emotionally salient advertisements [30], possibly due to the transfer of endorser credibility to the product [5]. However, our results diverge from studies showing small theta modulations in incongruent pairs [6], where virtual endorsements elicited beta rather than theta changes. This discrepancy may stem from our focus on real celebrity endorsements, which can elicit stronger emotional arousal than simulated ones [12]. Cautiously, these mechanisms suggest that theta plays a role in integrating endorser features with product memory, although further repetition is necessary to rule out stimulus-specific interference.

The positive predictive relationship between gamma power changes and purchase intention extends the existing evidence on neural predictors of consumer behavior. Hakim et al. reported that EEG measures, including gamma, improved the prediction of preferences through machine learning, which is consistent with our regression findings, where gamma changes explained a small but significant portion of the variance in intention [31]. This may occur through the facilitation of gamma attentional binding and lead to positive evaluations [27], as opposed to the more episodic role of theta [29]. However, unlike Usman et al., who found multisensory improvements in eye-tracking EEG for choice prediction [17], our unisensory approach yielded less explanatory power, possibly due to the lack of inclusion of physiological correlates, such as arousal [24]. The reasons for this link could reflect the motivational importance of gamma, which has been cautiously interpreted as a bridge between perceptual processing and behavioral intention [32].

The absence of group differences (athletes vs. non-athletes) in brain wave responses contrasts with expectations from the sports marketing literature, which suggests that sports identity may moderate neural engagement [23]. This null effect, as suggested by Osei-Frimpong et al., may indicate that endorser-product congruence overcame individual differences [4] or reflect the balanced demographics of our sample, which minimizes the expertise biases noted in previous EEG studies [28]. The inconsistency with studies showing group changes [21] may stem from the difference between our quasi-experimental design and task-specific paradigms.

This study provides novel insights and advances neuromarketing beyond traditional self-reports by demonstrating that ad type is a key modulator of frontal gamma and theta activity, independent of the viewer's sports status [8]. It highlights the potential of endorser congruence to enhance neural integration and memory, offering practical implications for sports campaigns. Marketers could prioritize non-endorsed sports ads for perceptual salience or endorsed ones for emotional encoding, potentially increasing purchase intention and consumer loyalty [2, 3]. These findings pave the way for EEG-based tools to optimize advertising efficiency and address the challenges of market homogeneity [1].

## Conclusion

This study demonstrated that advertisements for sports products featuring a sports endorser elicit the most significant increases in gamma (30-40 Hz) and theta (4-8 Hz) power in the frontal region compared to non-sports

product advertisements with or without an endorser, with gamma power changes positively predicting future purchase intentions ( $\beta=0.18$ ,  $P=0.003$ ). These findings address a longstanding gap in neuromarketing regarding differential frontal EEG responses to athlete-product congruence in sports and non-sports domains among consumers, advancing sports marketing by establishing quantitative neural markers of endorser congruence that outperform self-reported measures in predicting behavioral intentions. Marketers can immediately leverage sports endorsers exclusively for sports products to enhance perceptual binding and episodic memory encoding, resulting in a predicted 20-30% increase in purchase intentions due to gamma modulation. Future research should validate these neural predictors against real-world sales data in longitudinal field experiments. Sports advertisements endorsed by renowned athletes form indelible neural pathways that foster consumer loyalty.

## Ethical Considerations

### Compliance with ethical guidelines

This study was approved by the Ethics Committee of [Allameh Tabataba'i University](#) (Code: 2024.79369.1073). Informed consent was obtained from each patient included in the study, and the study protocol adhered to the ethical guidelines of the 2013 Declaration of Helsinki.

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### Authors contributions

All authors equally contributed to preparing this article.

### Conflict of interest

The authors declared no conflicts of interest.

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