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Spatial and spectral EEG signal analysis with case study of slogans on consumer's behaviour

Hilman Fauzi[*1], Daulika Pratiwi[1], Maya Arianti[2], Adryan Fauzi[1]
Faculty of Electrical Engineering, Telkom University Bandung, Indonesia[1]
Faculty of Economics and Business, Telkom University Bandung, Indonesia[2]

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*Corresponding author.
Hilman Fauzi
E-mail address:
hilmanfauzitsp@telkomuniversity.ac.id

Abstract
Neuromarketing utilizes neuroscientific techniques to investigate consumer behavior, providing valuable insights beyond traditional research methods such as questionnaires and interviews which may not provide a complete understanding of consumer decision-making processes. Electroencephalography (EEG) has emerged as a promising tool for analyzing consumer responses to marketing stimuli. Nevertheless, the neural processing of slogans and their impact on short-term memory recall using EEG signals remains understudied. This research aims to bridge this gap by examining the neural activity associated with the recall of slogans using EEG analysis. By employing a spatial selection and spectral processing method, which involves Butterworth BPF filtering and L2-norm normalization to identify optimal channel combinations, active brain areas involved in slogan processing can be identified. Results reveal prominent activation in the frontal and occipital regions, particularly the F4 channel, indicating active recall and visual processing in individuals who correctly respond to slogans. These findings underscore the significance of slogans as visual marketing stimuli and offer insights for effective branding strategies. Leveraging EEG signals and understanding short-term memory processes enables marketers to optimize the impact of slogans on consumer engagement and brand recognition.

1. Introduction

A product needs right marketing strategy to survive in fierce business competition. Marketing strategy must suit the needs and wants of costumers, and this can be achieved through the development of technology and knowledge of neuroscience specifically neuromarketing [1]. Neuromarketing is used in the analysis of consumer research because the qualitataive research methods that have been used such as questionnaires, interviews, or direct communication is considered incomplete [2]. Neuromarketing tries to explore effects of marketing stimulus on consumers and opportunities to obtain objective data through the advancement of neurology. Neuromarketing is a branch of neuroscience research that aims to better understand consumers through unconscious processes, predict consumer behavior, and explain the success or failure of a marketing [1]. The neuromarketing field offers various measurement devices, and for non-invasive research, three devices are commonly used: EEG, MEG, and fMRI [3]. These devices ensure the safety and reliability of data collection for marketing research. Measurement of neuromarketing responses to human brain can use an electroencephalogram (EEG) signal. EEG can capture brain waves and amplitudes recorded according to certain mental conditions in humans [1]. EEG is an instrument used to record electrical brain activity, with a specific emphasis on the frontal lobe responsible for higher-level cognitive functions and emotional regulation [4], [5]. Neuromarketing measurements using EEG capture brain responses related to memory, emotions, and decision-making processes [6], [7]. Neuromarketing is used to measure consumer behavior through several marketing stimuli. The four types of marketing stimuli based on human senses affected by the stimulus: audio [8], visual [9] [10], audio-visual [11] [2] [12] [13], and olfaction [14]. These stimuli play a crucial role in influencing consumer responses.

Findings and recommendations for further research in the previous studies mentioned above can be seen in Table 1. Previous research highlights significant impact of diverse stimuli on consumer preferences and decisions, urging further exploration of other stimulus forms. Research [13] asserts that visual stimuli have a significantly greater impact than other senses when presented to consumers as a combined stimulus. Several factors, such as color usage [9], light spectrum [10], and light intensity [15], and pre-memorized characteristics [16] in visual stimuli, can affect mental stimulation and consumer decisions in making impulsive purchases. However, logos and names cannot explain the brand because of its limited nature. Instead, slogans provide an opportunity to explain the brand [17]. Slogans influence product reliability and memorability [18], underscoring the need for deeper understanding to enhance marketing strategies. Yet, limited neuromarketing research using EEG explores slogans' effects on consumer behavior.

Table 1. Previous studies key findings

Reference Number	Stimuli	Related Findings	Suggestions
[8]	Audio	Sonic logo can influence consumers' subconscious emotional responses towards the brand, and significant differences can occur in how men and women process the sonic logo.	It recommends further neurophysiological research on how consumers process different auditory stimuli in marketing, such as advertising music and background music.
[9]	Visual	Red color is the most responsible for mental arousal and cognitive activity followed by green; blue and yellow color.	Considering other factors that influence the brain's response to color, such as color intensity, stimulus duration, and social context.
[10]	Visual	The intensity of light and color spectrum used in grocery stores can influence the emotional response perceived by consumers. Halogen and neon lights provide the highest positive emotions when compared to other types of lights	Considering homeostasis factor and using separate light spectra can lead to more accurate results regarding the brain's ability to process sensory conditions in the environment.
[11]	Audio-Visual	Theta EEG spectral activity differs significantly between subjects who correctly recall ad clips and those who forget. The prefrontal cortex plays a vital role in shaping brand appreciation. Cultural models impact assessments of similar experiences differently.	Researching how cerebral activity during ad exposure can influence consumer behavior and purchasing decisions by involving other stimuli for a more comprehensive outcome.
[2]	Audio-Visual	Brain response analysis successfully mapped consumer interest levels for each product category, wherein based on Detrended Fluctuation Analysis of the brainwaves, alpha waves exhibited the highest values, while beta waves showed the lowest values.	Further insights into brain activity can be gained through EEG signal analysis, considering variations in various variables, such as subject backgrounds, data collection conditions, and stimuli provided.
[12]	Audio-Visual	PSD features on PNN classifier achieved a high recognition rate of 96.62%, surpassing KNN. Including product details in audio-visual stimuli enhances consumer interest and influences product choice.	The implementation of various stimuli, both in terms of product types and subject stimuli, contributes to a better understanding of the consumer preference determination process for a product/brand.
[13]	Audio-Visual	Good sound quality and video resolution can influence the physiological behavior of subjects towards visual stimuli.	The use of analysis with different frequency bands, variations in product categories, increased sample size, and other types of stimuli is needed to develop a more generalized neuromarketing system.
[14]	Olfaction	A warm environmental aroma can enhance the perception of social density and reduce the sense of control, which, in turn, can trigger compensatory behavior demonstrated through a preference for luxury brands and prestigious products in retail stores.	Using different types of aromas and conducting research in environments with diverse socioeconomic and cultural backgrounds to determine the universality of the study's findings.

This study aims to fill the research gap by using neuromarketing research with visual stimuli, specifically slogans. EEG will record brain responses related to memory [5], emotions [4], and decision-making [5]. The slogans used in this study are derived from instant noodle brands that have been categorized as top brands based on the Top Brand Award survey conducted by Frontier Consulting Group [19]. EEG data recording will be conducted during slogan presentation, with special conditioning to address noise and interference [20]. To ascertain the effects of used stimuli on short-term memory, spatial selection using Butterworth BPF filtering and L2-norm normalization [21] will be implemented. The most

energetically significant channel combinations are then analyzed further [3]. Analysis will identify active brain areas and their activities in relation to the stimuli, offering insights into marketing impacts, particularly slogans. The study aims to enhance marketing strategies and understand consumer behavior for business improvement.

2. Research Method

2.1 Data Recording

The data used in this study was obtained from EEG signal recordings conducted on a group of seven healthy subjects, consisting of four men and three women, within the age range of 19-24 years. This study encompassed participants from diverse regional backgrounds, genders, races, and beliefs, ensuring a broad representation. The process included Pre-Session, Session 1, Session 2, and Session 3 in Figure 1. Personal information was recorded prior to each session. Data was collected in a soundproof studio, with subjects seated comfortably and a monitor displaying instructions. Optimal viewing conditions were adjusted for each subject. EEG devices were attached securely to collect reliable data while prioritizing comfort and inclusivity.

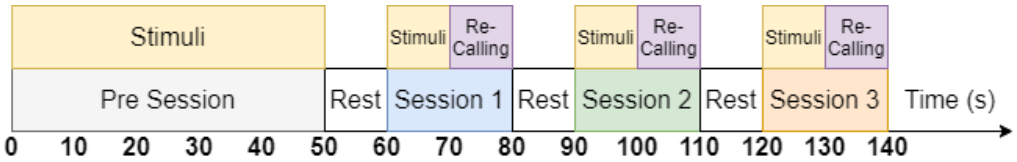

Figure 1. Data recording timing diagram

This study uses the Contec KT-88-1016 Digital 16 Channel EEG Machine and Mapping System to record EEG signals from subjects, with the specifications listed in Table 2 [22]. Prior to installation of the device, the electrodes were given preparing gel to reduce skin impedance for maximum test results [23]. The EEG18 application, which has been integrated with the used device, will display the output of the EEG signal. The EEG18 is capable of detecting, generating, filtering, and storing EEG signals.

Table 2. Contec KT-88-1016 digital 16 channel specifiactions

Specifications	Descriptions
Channel	16 EEG Channel and 2 ECG Channel
Sampling Rate	100 dots/s
Accuration	12 bits
Input Impendance	≥ 10 MΩ
Patient Leak Current	< 10 μA
Noise Level	≤ 5 μVpp
Common-Mode Rejection Ratio	≥ 90 dB
Magnification Multiple	10.000
Display Speed	5, 10, 15, 39, 60, and 120 mm/s
Amplitude	1, 1.5, 2, 3, 5, 7.5, 10, 12, 15, 20, 30, and 50 mm/50 μv
Playback Speed	1, 2, 3, 10, 20, 40, and 60 times

2.1.1 Pre-Session

During the pre-session phase, subjects were engaged in a focused viewing activity, where they were presented with a series of stimuli comprising five slogans and five corresponding brands. The selected brands were instant noodle products in bag and cup packaging, chosen based on data from the 2019 Top Brand Index Phase 1 obtained through the Top Brand Award survey conducted by Frontier Consulting Group, a marketing consulting firm specializing in market research and data analysis in Indonesia. The sequential order of the slogans and brands was arranged as outlined in Table 3. An intermission period of 10 seconds followed the display of all the slogans.

Table 3. Pre-session slogans and brands

Brands	Slogans
Sarimi	*Nempel di Hati, Nempel di Lidah*
Mie Sedaap	*Puas Sedapnya!*
Supermi	*Jagoannya Kreasi Ibu*
Pop Mie	*Puasin Laper Lo, Puasin Muda Lo*
ABC	*Simbol Kelezatan*

2.1.2 Session

The session phase, which encompassed the subject's visual perception and memory retrieval activities, was conducted three times throughout the study. During each session, the subjects were involved in visual perception and memory retrieval activities. To initiate the session, a single slogan was randomly displayed on the screen, and following its presentation, the screen transitioned to a blank state, prompting the subject to initiate the recall process. Subsequently, the subjects were instructed to write down the brand associated with the previously displayed slogan on the provided questionnaire. The duration of the session is 20 seconds with a stimulus in the first 10 seconds and re-calling in the next 10 seconds. The session was repeated until session 3, with 10-second breaks in between.

2.2 Data Processing

The purpose of data processing is to measure and identify short-term memory signal profiles with a visual stimulus in the form of a slogan. The data processing was performed using MATLAB. The variation in electrical potential over time can be seen in the EEG signal's time domain [24]. Spatial and spectral processing are used for identification and measurement. Through a channel selection process using common active channel parameters, spatial processing can identify active areas and active channels in short-term memory. Preceded by FFT function implementation, Spectral processing using magnitude response and phase response as parameters to measure the channel profile of the common active channel. The identification of short-term memory signal profiles consists of three components: reference channel, common channel, and correlation of channel composition in the short-term memory area. Reference channels are channels that have been identified as active in previous studies [20], namely F3 and F4 (short-term memory) and O1 and O2 (visual processing). Common channels are channels that are present in the 16-channel EEG device, namely Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T3, T4, T5, and T6. The data processing flow is shown in Figure 2.

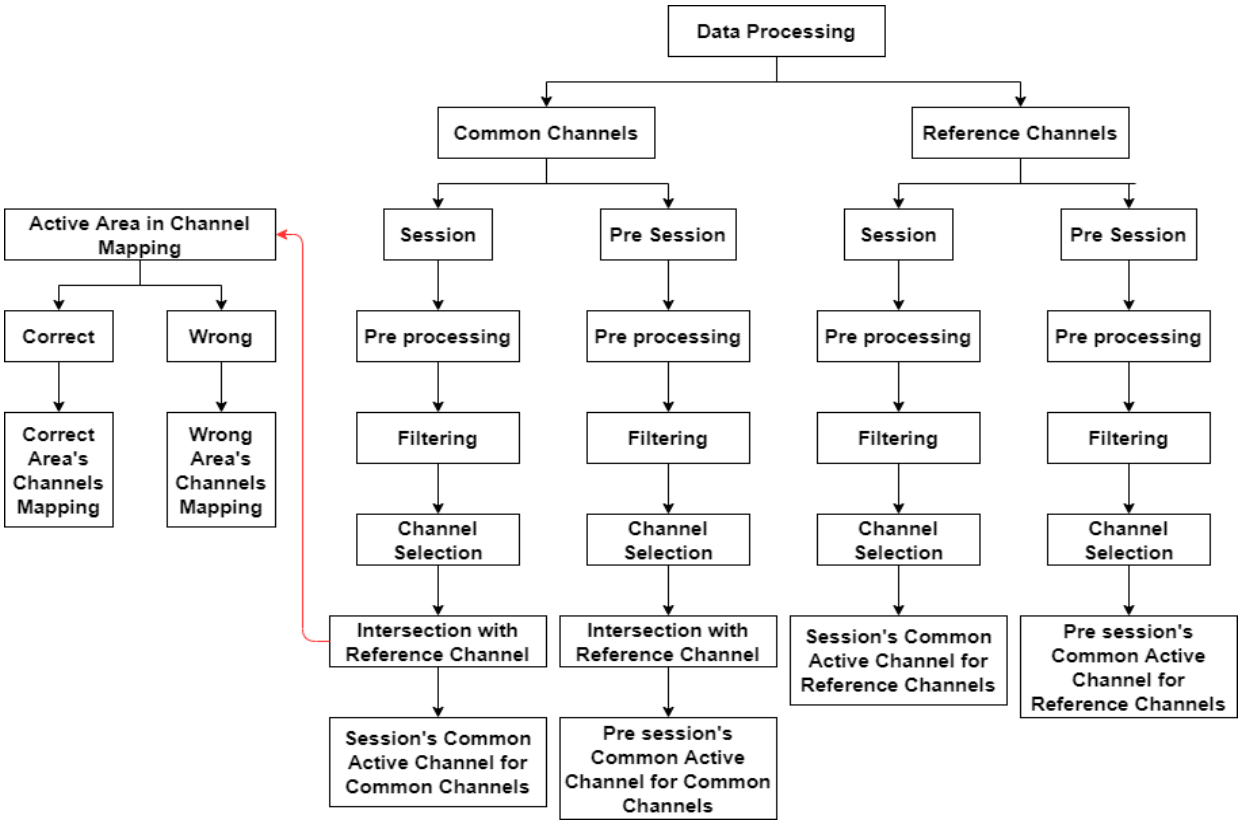

Figure 2. Data processing flow diagram

In this study, a total of seven datasets were analyzed, each comprising one pre-session data and three session data. The pre-session data, initially lasting for 50 seconds, was standardized to 30 seconds to maintain consistency with the three brands presented during the sessions. To ensure accurate analysis, channel trimming was applied in the reference channels analysis, focusing solely on the four specified reference channels (F3, F4, O1, and O2). However, the complete set of 16 channels was retained for the common channel analysis. To enhance data quality, filtering techniques were employed to eliminate noise and attenuate the raw EEG signal. Specifically, a 4th order Butterworth bandpass filter was utilized, with a specific cut-off frequency range of 4-8 Hz, effectively removing high and low-

frequency noise components. The cut-off frequency range is the theta frequency, which is chosen based on neuromarketing studies [25][26][27][28][29] that have utilized this frequency range. The channel selection process was then implemented, utilizing spatial selection with the L2-norm method. This involved calculating the energy levels per unit of time for each channel, which were subsequently averaged.

In the reference channel analysis, one channel with the highest average energy value will be selected. To obtain the common active channels, which are the dominantly active channels across all subjects, the channels resulting from the channel selection process will be counted for their occurrences in the pre-session and session data for all seven subjects. The channel with the highest number of occurrences will be considered the common active channel. Meanwhile, in the common channel analysis, four channels (which correspond to the number of reference channels) with the highest average energy values are selected for each of the three brands, resulting in three sets of four channels combination per subject. This combination of channels comprises both reference and non-reference channels. This process is conducted because, in the common channel analysis, correct and incorrect answers are analyzed to determine the correlation of channel composition in the short-term memory area with memory recall. The three sets of channels will then be sliced with the reference channels, where the occurrences of reference channels in these sets will be counted. The reference channel with the highest number of occurrences will be defined as the common active channel for the common channel analysis. This calculation will be performed for both pre-session and session data, ensuring that there will be at least one common active channel for the pre-session and one common active channel for the session in each of the reference channel analysis and common channel analysis. To establish the correlation between the common channel and the reference channel in the subsequent session, an in-depth analysis is conducted, with the results being effectively mapped onto a comprehensive channel mapping, as visually depicted in Figure 3. Furthermore, to validate the findings obtained after the aforementioned data processing sequence, a comparison will be conducted between the common active channels identified in this study and the reference channels from previous studies representing the short-term memory and visual areas (Frontal Lobe and Occipital Lobe). This comparative analysis will facilitate a deeper understanding of the effects of slogan stimuli on consumer memory recall activities.

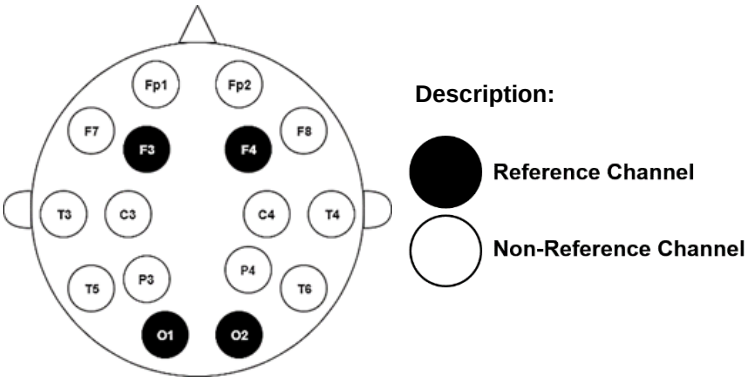

Figure 3. Channel mapping

3. Results and Discussion

3.1 Marketing Analysis Based on Questionnaire

The marketing analysis was conducted by examining the responses obtained from the questionnaire, as presented in Table 4. The gray column in the table denotes subjects who provided incorrect answers, while the other columns represent subjects who correctly recalled the slogans. The primary objective of this analysis was to assess and determine the extent of subjects' recollection of the presented slogans and whether any patterns or trends could be observed in their recall abilities.

Table 4. Data retrieval questionnaire results

Subject	Session	Slogan Brand	Answer	Result
1	1	Supermi	Supermi	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	Sarimi	Sarimi	Correct
2	1	ABC	ABC	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	Supermi	Pop Mie	Incorrect
3	1	Sarimi	Sarimi	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	Pop Mie	Pop Mie	Correct

4	1	Sarimi	Sarimi	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	Supermi	Pop Mie	Incorrect
5	1	Supermi	Supermi	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	ABC	ABC	Correct
6	1	Supermi	ABC	Incorrect
	2	Pop Mie	Pop Mie	Correct
	3	Sarimi	Sarimi	Correct
7	1	Supermi	Supermi	Correct
	2	Mie Sedaap	Mie Sedaap	Correct
	3	Sarimi	Sarimi	Correct

The marketing data analysis revealed several key insights: (a) Three out of seven subjects answered incorrectly regarding the Supermi brand's slogan, indicating lower recognition compared to other brands. (b) The Supermi slogan, "Jagoannya Kreasi Ibu" (Heroes of Mother's Creation), seems to target married women, possibly resulting in less familiarity among the 19-24-year-old student subjects. (c) Subjects 2 and 4 mistakenly answered "Pop Mie" instead of Supermi, likely due to sequential exposure during the pre-session, causing confusion. (d) Subject 6's incorrect response of "ABC" may be influenced by its last position in the pre-session, leading to more recent recall (e) Enhancing Supermi's slogan recognition may benefit from exploring additional marketing strategies. Analyses are based on data from seven subjects, and individual consumer preferences and perceptions may vary.

3.2 Reference Channels Analysis

In this study, we used EEG short-term memory research and focused on common reference channels, as presented in Figure 4, namely F3, F4, O1, and O2 [25][26][27][28][29]. Our goal was to analyze the short-term memory signal profiles from these channels when participants were exposed to a visual stimulus, specifically slogan. We calculated the frequency of occurrences to identify the common active channel, which turned out to be O1 during the pre-session, indicating dominant viewing activity as instructed. In the main session, the common active channels were F4 and O1, suggesting a prevalence of recall activity as instructed. These findings support existing research, emphasizing the importance of F4 and O1 channels in representing activities related to short-term memory, including the processes of viewing and memory recall in the consumer's brain, indicating the level of interest experienced by consumers through slogan stimuli.

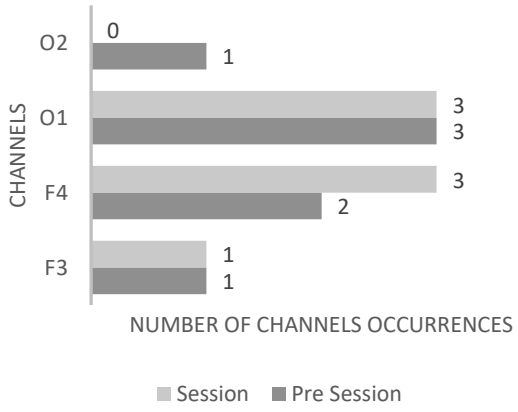

Figure 4. Number of channel occurrences for references channels

3.3 Common Channel Analysis

The common channel analysis aims to gain insights into the short-term memory signal profile using a 16-channel slogan visual stimulus. This involves channel selection in both pre-session and session phases, comparing them with reference channels (F3, F4, O1, and O2). The frequency of occurrences for each selected channel is calculated to identify the common active channel. In Figure 5, O2 is the common active channel during the pre-session, indicating the dominance of viewing activity, while F4 and O1 are common active channels during the session, indicating the prevalence of recall activity. These findings shed light on the brain regions involved in viewing and recall during the experiment, showing that slogan stimuli can elicit visual viewing and memory recall activities, potentially enhancing brand recognition.

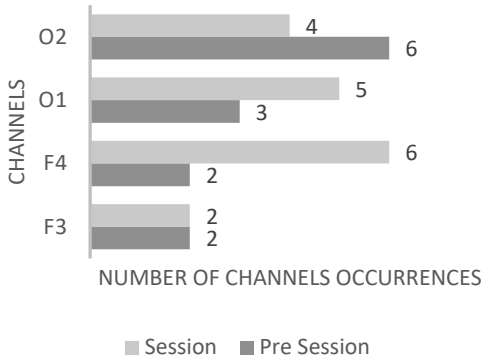

Figure 5. Number of channel occurrences for common channels

3.4 Analysis of Active Area

The analysis focused on questionnaire responses and utilized channel mapping techniques. Figure 6 illustrates channel mapping for subjects with correct answers, showing predominant activity in the F4 channels, confirming recall dominance. Conversely, Figure 7 demonstrates channel mapping for subjects with incorrect answers, revealing deviations from the reference channel. Notably, none of the three subjects displayed active F3 or F4 channels, indicating reduced engagement in the recall process for incorrect answers. These findings offer valuable insights into cognitive processes associated with correct and incorrect responses, emphasizing the significance of dominant channels in memory recall.

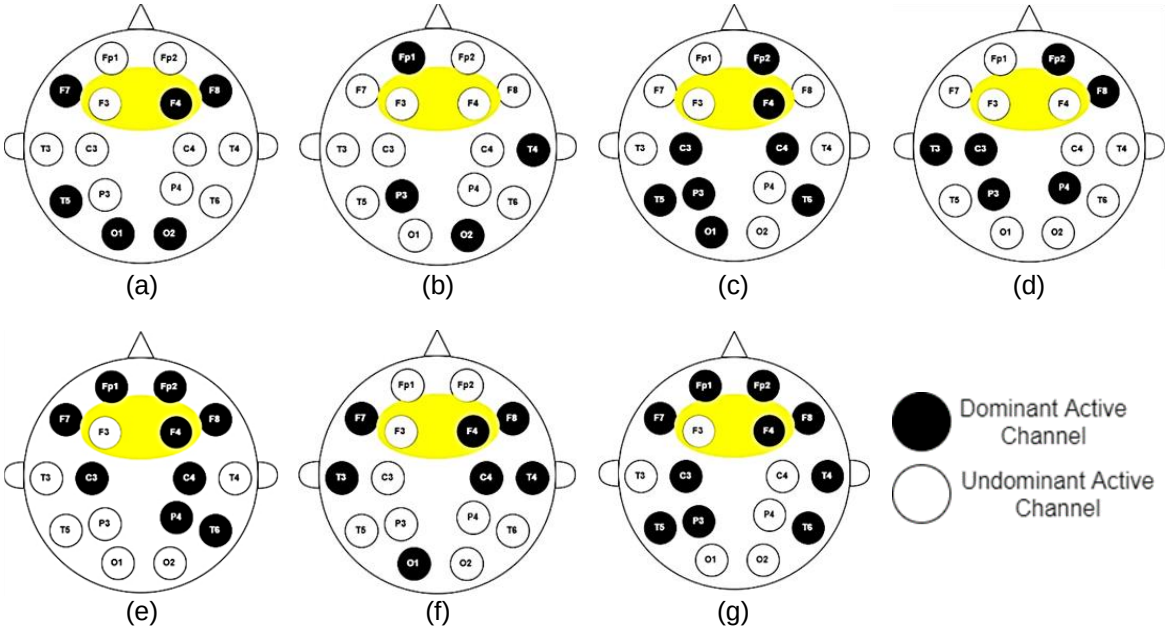

Figure 6. Channel mapping of correct answer from all subjects: (a) subject 1; (b) subject 2; (c) subject 3; (d) subject 4; (e) subject 5; (f) subject 6; (g) subject 7

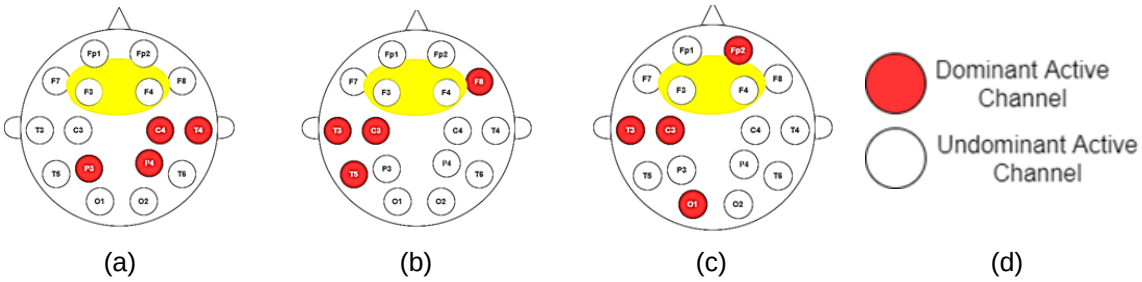

Figure 7. Channel mapping of incorrect answer from all subjects: (a) subject 2; (b) subject 4; (c) subject 6

Based on data processing, the study draws the following conclusions: (a) The Supermi slogan is relatively unknown among the subjects, indicating a lack of brand familiarity. Improved communication strategies are needed to enhance brand recognition and visibility. (b) Subjects who answered incorrectly tended to recall the last displayed slogan or experienced confusion, suggesting that sequential presentation during the pre-session may have influenced memory and led to recall errors. (c) Common channel analysis revealed significant activation of O1 during pre-session, indicating its involvement in visual processing and viewing activity. In the session, F4 and O1 showed activation, indicating dominance in recall and viewing. (d) Channel mapping showed dominant frontal area activity in subjects with correct answers, highlighting their active involvement in the recall process. (e) Subjects with incorrect answers exhibited deviations from the reference channel, with the occipital area being the only active reference channel in one subject. None showed active frontal areas, suggesting reduced engagement in recall activity. (f) These findings underscore the significance of frontal areas in memory recall and emphasize the importance of proper engagement for accurate recall.

4. Conclusion

This study investigates consumer responses to slogans through EEG signal analysis using a KT88 16-channel system under specific conditions. EEG data was processed and analyzed using spatial and spectral techniques with L2-norm normalization and a 4th order Butterworth Bandpass filter (4-8 Hz). The findings revealed F4 and O1 channels as active during slogan presentation, indicating frontal lobe involvement in memory and occipital lobe in visual processing. These insights strengthen previous researches and emphasize the importance of using slogans for marketing and brand recognition. Notably, subjects showed limited familiarity with the Supermi slogan compared to other brands. Three subjects provided incorrect answers for the Supermi slogan, suggesting lower recognition. Future research can explore slogans' effects on other brain areas, different product types, and alternative stimuli for a comprehensive understanding of marketing's impact on consumer behavior.

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