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Like/dislike analysis using EEG: Determination of most discriminative channels and frequencies

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ABSTRACT

In this study, we have analyzed electroencephalography (EEG) signals to investigate the following issues, (i) which frequencies and EEG channels could be relatively better indicators of preference (like or dislike decisions) of consumer products, (ii) timing characteristic of "like" decisions during such mental processes. For this purpose, we have obtained multi-channel EEG recordings from 15 subjects, during total of 16 epochs of 10 s long, while they were presented with some shoe photographs. When they liked a specific shoe, they pressed on a button and marked the time of this activity and the particular epoch was labeled as a LIKE case. No button press meant that the subject did not like the particular shoe that was displayed and corresponding epoch designated as a DISLIKE case. After preprocessing, power spectral density (PSD) of EEG data was estimated at different frequencies (4, 5, . . ., 40 Hz) using the Burg method, for each epoch corresponding to one shoe presentation. Each subject's data consisted of normalized PSD values (NPVs) from all LIKE and DISLIKE cases/epochs coming from all 19 EEG channels. In order to determine the most discriminative frequencies and channels, we have utilized logistic regression, where LIKE/DISLIKE status was used as a categorical (binary) response variable and corresponding NPVs were the continuously valued input variables or predictors. We observed that when all the NPVs (total of 37) are used as predictors, the regression problem was becoming ill-posed due to large number of predictors (compared to the number of samples) and high correlation among predictors. To circumvent this issue, we have divided the frequency band into low frequency (LF) 4–19 Hz and high frequency (HF) 20–40 Hz bands and analyzed the influence of the NPV in these bands separately. Then, using the *p*-values that indicate how significantly estimated predictor weights are different than zero, we have determined the NPVs and channels that are more influential in determining the outcome, i.e., like/dislike decision. In the LF band, 4 and 5 Hz were found to be the most discriminative frequencies (MDFs). In the HF band, none of the frequencies seemed offer significant information. When both male and female data was used, in the LF band, a frontal channel on the left (F7-A1) and a temporal channel on the right (T6-A2) were found to be the most discriminative channels (MDCs). In the HF band, MDCs were central (Cz-A1) and occipital on the left (O1-A1) channels. The results of like timings suggest that male and female behavior for this set of stimulant images were similar.

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1. Introduction

The fundamental goal of marketing professionals is to guide the design and presentation of products in a way that they are well suited to consumer preferences. To understand the preferences, these professionals often use several standard research tools, such as one-on-one interviews with the consumers, general surveys, and focus group studies. These approaches are easy and inexpensive to implement but they provide data that can contain biases, and are therefore perceived as not very correct [1].

Neuro-marketing is a relatively new research field that studies human brain's response to commercials, brands, and other marketing stimuli. In this field, various neuro-scientific methods are used to analyze and understand consumer behavior associated with purchasing preferences. These methods include the brain imaging technologies such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), magneto-encephalography (MEG), and steady state topography (SST), and physiological parameters like heart rate, respiratory rate, and galvanic skin response (GSR) [2,3].

The motivation behind the use of these technologies is to have access to hidden information about the consumer experience instead of just asking his/her preference. It is assumed that such hidden information may be used to influence purchasing behavior, thus the cost of doing neuro-scientific studies would be compensated by the benefit of better product design and sales [4].

Nowadays, functional Magnetic Resonance Image (fMRI) technique is drawing increasing interest from the neuro-marketing community. It is based on imaging of the blood flow in the brain and helps identifying areas activated by a stimulus. The spatial resolution offered by this technology is superior to any other imaging method currently available. However, poor temporal resolution due to delay between a particular stimulus and the blood flow to the activated locations makes fMRI inappropriate for tracking the fast brain dynamics, and is an expensive technology. On the other hand, EEG and MEG are brain-imaging tools that provide high temporal resolution with inferior spatial resolution compared to fMRI. MEG systems are expensive and require shielded environments in order to detect very low magnetic fields generated by the brain. EEG technology is a relatively inexpensive, well established, and robust tool that has been attractive to neuro-marketing community since its first use in this field in 1971 by Krugman [5]. We also believe that we can enhance our understanding of the dynamics of brain (during some decision making processes) using EEG analysis as a practical and efficient tool.

In order to test a hypothesis in neuro-marketing or similar studies first a stimulus set and test protocol is prepared. The subject is exposed to the stimuli according to the protocol and electrical signals from different locations on the brain surface are acquired as multichannel EEG. After data acquisition, noise and artifacts that may overshadow the real changes in the signals are removed using various signal processing techniques such as filtering, independent component analysis and principle component analysis [6–8]. The resulting data set is then analyzed and some desired features (e.g., power spectra) are extracted [9]. These features coming from different stimuli and subjects are statistically analyzed to answer the questions under investigation.

In most of the EEG based studies, desired features are derived from frequency bands of the signal (especially theta, alpha, beta and gamma). The delta waves lie within the range of 0.5–4 Hz. These waves are mainly related with deep sleep and may exist in the waking state. It is very easy to confuse artifacts caused by the neck and jaw muscles with the real delta response. Theta waves, on the other hand, have been associated with access to unconscious material, creative inspiration and deep meditation. Theta waves arise from emotional stress, especially frustration or disappointment. In the alpha waves, the rate of change lies between 8 and 13 Hz. Alpha waves have been thought to indicate both a relaxed awareness and also inattention, and are strongest over the occipital and frontal cortex. Beta waves arise within the range of 13–30 Hz, and are associated with active thinking, active attention, and focus on the outside world or solving concrete problems. Gamma waves oscillate at frequencies beyond 30 Hz and mostly observed during cross-modal sensory processing, short-term memory matching of recognized objects, sounds, or tactile sensations [10–12]. A decade ago, Başar et al. [13] gave an overview on brain waves associated with different functions and mechanism of processing of emotional information. It has also been shown by several researchers that several brain regions such as the ventromedial and dorsolateral prefrontal cortex, amygdala, ventral striatum, anterior cingulate and insular cortex are important for human affective response [14].

In this particular study, we employed recordings from 19-channel EEG system in order to investigate the answers to the following two questions: (1) Which frequencies and channels (i.e., brain surface areas, not specific points) are critical and need special attention in the discrimination of like/dislike preference of products? (2) What is the characteristic of timings of like decisions?

2. Materials and methods

2.1. Study population and signal acquisition

In order to screen possible effects of 'age' (i.e., the reflection of decision processes on the EEG signals can be age dependent) in our analysis, we have recruited an age controlled group of 15 volunteers to participate in our study. We also aimed at exploring possible influence of gender in our results, so we have included both genders (10 female, 5 male) in our study group. Age profile of our subjects was as follows: Range 19–25, mean ± std age is 22 ± 1.6. All of the subjects signed an informed consent before the experiments and our study was approved by the Research Ethics Committee of Erciyes University.

In our trials, we recorded 21-channels of electroencephalography (EEG) signals using international 10–20 system [15]. We used 19 of these EEG channels in our analysis of characteristics of like/dislike decisions. Fig. 1 shows montage of these channels on a polar projected circular model head. Our recording system (EEG 1200, Nihon Kohden Co., Tokyo, Japan)