Neurophysiological Test with Use of EEG, GSR and Pulse Measurements Data for Focus Group Beverage Preference Aggregation

Stanimir Andonov
Economics, Industrial Engineering and Managemen Department,
Management Faculty
Technical University - Sofia
stanimir.andonov@tu-sofia.bg

Stiliyan Georgiev
Validation – Vision Analysis Team
Visteon Electronics Bulgaria
Sofia, Bulgaria
stilliyan@gmail.com

Georgi Tsenov
Fundamentals of Theoretical Electrical Engineering Department,
Automatic Control Faculty
Technical University - Sofia
gogotzenov@tu-sofia.bg

Valeri Mladenov
Fundamentals of Theoretical Electrical Engineering Department,
Automatic Control Faculty
Technical University - Sofia
valerim@tu-sofia.bg

***Abstract* — The primary objective in this case study is introduction of a testing methodology framework for assessing the effectiveness of different drinks and flavors through neuromarketing. The framework involves use of focus groups for evaluation of the neurophysiological reactions of participants to various stimuli and drawing statistically significant conclusions based on the results. In the last past decade, there has been an increase in the availability of affordable and easy-to-use biosensors that provides the possibility for affordable and easy to use real-time measurements of bio-signals, such as electroencephalography (EEG), galvanic skin response (GSR), and pulse. Also, with the recent ongoing increase of the computational capabilities the signal processing and analysis of the recorded biometric data can also be processed in real-time with relatively affordable and mobile hardware. By analyzing these signals and identifying an informative features that are derived statistically from group averaging and independent of individual user's deviations, it is possible to classify and then apply the measured brainwaves and other biometrics data in various applications. In this paper, the authors apply data from voltage potential electrodes EEG brainwaves, along with GSR and pulse in order to recognize the variation response levels among a sample focus group and the results for determination of their aggregated preferences on tested sample drinks.**

Keywords—biosignal feedback, electroencephalography, feature extraction, neuromarketing, signal processing.

I. INTRODUCTION

Traditionally, the assessment of product quality, taste, and marketing materials relied on expert opinions or feedback from focus groups who answered pre-determined questions. However, recent technological advancements have made it possible to record and measure multi-channel biomedical data that was previously limited to hospitals and labs. Alongside these advancements, progress has been made in the field of deep learning neural networks, allowing for real-time processing of large amounts of biosignal data to determine relevant features associated with a person's neurophysiological response to complex marketing incentives. This approach has given rise to a new marketing testing method called neuromarketing, which combines neuroscience and marketing. By utilizing advanced technology, neuromarketing examines the brain and physiological reactions of individuals to specific stimuli in order to evaluate their response to marketing. These responses are typically involuntary and cannot be manipulated, thus providing more dependable and meaningful data compared to conventional methods like focus groups and interviews.

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Companies often use neuromarketing to uncover consumers subconscious reactions to various marketing stimuli, including brand associations, logos, slogans, advertising clips, campaigns, and products. Researchers use techniques such as electroencephalography to measure brain responses of study participants to identify specific stimuli that trigger desired behaviors, such as trying a new product. Using this information, companies can design marketing campaigns that take advantage of these stimuli to encourage these behaviors, even if specific subject studies were not conducted for that particular campaign. Companies can also utilize neuromarketing when introducing a new food or beverage line targeting a specific group of consumers. Historically, companies like Coca-Cola and PepsiCo have modified the formulas of their main products or introduced new ones, and have relied on focus groups and surveys to determine which samples are most preferred. Nevertheless, this approach can be unreliable since participants may not always be aware of their true preferences and may provide inaccurate results. By directly measuring the brain's response using techniques such as electroencephalography, galvanic skin response, and pulse, the companies can obtain more authentic reactions from test subjects. Therefore, the authors of this paper have developed a procedure to extract drink taste evaluation results directly from neurophysiological reactions, similar to the approach used in neuromarketing and it is tested on a large enough focus grup. The paper is organized into several chapters, including an overview of neurometric and biosignals in Chapter 2, the methodology for taste of drinks evaluation and results in Chapter 3, and a Conclusion, Acknowledgement, and References section.

II. BIOMEDICALSIGNALS AND NEUROMETRICS USED

This category of the biometric techniques, that is known as biometrics, involves measuring physiological changes in test subjects, focusing on cognitive processes that do not involve recording brain activities [1]. Biometric methods include skin conductivity, electromyography, eye movement tracking, time for reaction, rate of heart pulses, facial expression analysis and voice analysis by frequency bands. In contrast, the neurometrics are referring to measurement techniques that concentrate on brain neuronal electrical activity and brain blood flow changes, such as electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI) [2], functional near-infrared spectroscopy (fNIR), and positron emission tomography (PET). The biometric measurements that are easiest to acquire and analyze are the changes of skin conductivity and heart pulse wave rate, while electroencephalography is the simplest neurometric measurement. The skin conductivity change is a phenomenon in which the human skin is becoming a better electrical conductor (having reduced resistance) during moments of physiological arousal, and is measured by recording the conductance of the skin. Arousal, referring to overall activation, is one of the two main emotional response dimensions and with strong confidence is a predictor of attention and memory. To measure it, a custom sensor is attached to a finger, which records data at a sample rate of 128 Hz and transmits it to a PC via USB interface.

The pulse, which refers to the number of heartbeats per minute (BPM), is a straightforward and reliable metric to capture and examine. Although respiration rate is also linked to heart rate, it is more challenging to measure, and so heart rate is typically preferred. An elevated heart rate can indicate heightened arousal. Several variables, such as mental stress, temperature of the body, and deprivation of sleep, can influence heart rate, and scientists are usually focused in detecting heart rate changes that are occurring over time, in order to identify deviations from a predetermined baseline. The benefits of measuring heart rate include its simplicity, affordability, and high reliability. Like measuring skin conductance, heart rate measurement can aid in gauging the level of nervous system arousal in response to specific stimuli. To obtain this biosignal, a watch with smart functions, equipped with pulse measurement capability was utilized, with wireless data transition via Bluetooth interface to a PC.

Electroencephalography is a technique used to record the brain electrical activity. This involves placing electrodes on the scalp to detect the electrical signals produced by the brain's neural cells, which communicate through electrical impulses. The electrical activity is captured in the form of waves from the brain, which can be divided and separated into different frequency bands. The alpha (α) band waves have a range of it’s frequency band from 8 to 13 Hz and an amplitude range of 30 to 50 μV. These waves are useful for measuring mental effort due to their higher amplitude. The beta (β) waves frequency band range is from 14 to 30 Hz in frequency and in amplitude is 5 to 20 μV, and can be measured from the brain’s frontal and central regions. Theta (θ) waves, which range from frequencies 4 to 8 Hz and have an less than 30 μV amplitude range, are linked with accessing unconscious materials, creative thinking, and deep meditation. Delta (δ) waves have a frequency range of 0.5 to 3 Hz and an amplitude of 100 to 200 μV, while gamma (γ) waves have a frequency range of 31 to 50 Hz and an 5 to 10 μV amplitudes, and are used to detect high cognitive activities. The 10-20 electrode placement International system is a method for recording spontaneous EEG, which involves placing electrodes on the scalp in specific locations that are defined in certain ratios. In fact the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull.

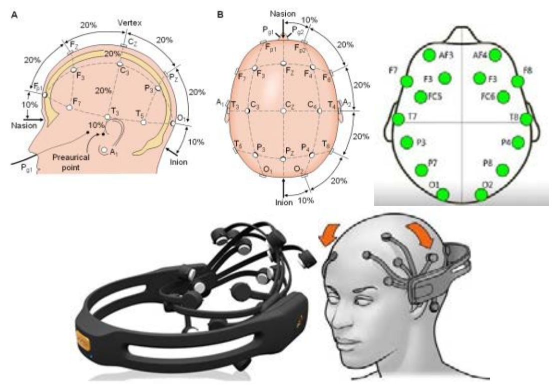


Fig. 1. The electroenchephalograph system “10-20” for electrode placement and EPOC+ EEG Emotiv headset system’s electrodes positions.

The position of the electrodes is defined by division of the skull surface area into sections using reference points on the head and measuring the sections in the transverse and median planes. The intervals of 10% and 20% are used to divide these sections, which determine the locations for electrode placement. For the measurement of EEG data we use, the "Emotiv EPOC" + headset with 2 reference and 14 data channels, and the data is transmitted wirelessly to a PC via Bluetooth. The data is initially sampled at a rate of 2048 Hz and then downsampled to 128 Hz, resulting in 64Hz baseband.

The cognitive index variable is presented and based on the cognitive load, where with ∂ is noted the cognitive index, $\in$b is the band power baseline intermission, and $\in$t notes the task internal band power. To measure cognition loads, bands are extracted, features are extracted, and then the data is classified.

$$\partial = 100\left(\frac{\in b - \in t}{\in b}\right) \quad (1)$$

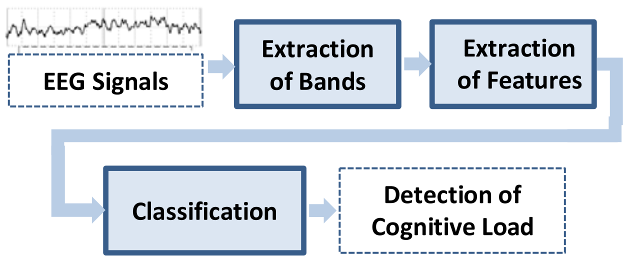


Fig. 2. The electroencephalography signal processing and classification

Fig. 2 shows how relevant features can be extracted from the raw signals of the EEG measurement. These features are observed in the Alpha and Theta frequency basebands, and have been found to be associated with memory and cognitive performance by Klimesch's clinical research [3], [4], [5]. In particular, changes in alpha and theta brain waves can serve as indicators for attention and memory, respectively. Thus, Alpha, Theta, and the Theta/Alpha ratio will be utilized for analysis. Furthermore, the electroencephalograph EMOTIV EPOC+ equipment has the ability to measure six basic emotional feature classes through a classifier provided by the EMOTIV Pro software suite with high resolution metrics. It is based on deep learning neural network that is trained with data from thousands of diverse participants. These feature classes are directly derived from the recorded brain activity of the subjects and offer an estimate of their mental states.

The study's neural network has the capability to measure six emotional states, including Stress, Engagement, Interest, Excitement, Focus, and Relaxation. To account for variations in skin conductivity/resistance or electrode wetness, we normalize the features and scale them to a range of 0 to 1. Stress measures comfort, with high levels indicating feeling overwhelmed and fear of negative consequences. Engagement measures alertness and conscious attention to task-relevant stimuli, characterized by increased physiological arousal and beta waves, whereas boredom is characterized by suppressed alpha waves. Interest measures the degree of attraction or aversion to external stimuli, with low scores indicating strong aversion and high scores indicating strong affinity. The utilization of bio-signals and feature extraction allows for the development of a test procedure that can statistically derive preference data from the neurophysiological responses of a significant focus group to external stimuli. In particular, the six emotional states of Stress, Engagement, Interest, Excitement, Focus, and Relaxation can be measured to provide insight into different aspects of cognitive and emotional processing. Excitement is an indicator of the level of physiological arousal, while Focus measures sustained attention and task switching. Relaxation assesses the ability to focus on a specific task and recover to a rest state. EEG and biometrics have been used in many studies to understand a human reactions to stimuli in visual and auditory modalities, and this information has been developed for neuromarketing uses in orded to evaluate the impact of variety of advertisements across different mediums [6], [7], [8], [9], [10], [11]. However, research on taste modality is still limited, and results are not tied to the aims of neuromarketing research [12], [13], [14], [15]. Hence, the present work aims to create and validate an experimental test set-up to record and process the neurophysiological responses to stimuli for taste, for the purposes of neuromarketing.

III. Experimental Results and Methodology Used for the Evaluation of Non Alcoholic Drink Taste

The preceding section outlines the signals and features that can be employed to establish an experimental setting. It is assumed that when participants taste a beverage, it elicits a neurophysiological reaction. To carry out the study, a methodology and toolset have been prepared for each participant. The study will involve three different beverages, which are yet to be introduced in the market and are variants of Schweppes Pomegranate, named Drink 198, Drink 618, and Drink 782, which are comparable in taste. The study was conducted on a focus group comprising eleven individuals of varying gender and age, as depicted in Figure 3.

Fig. 3. The test lab space and the tested sample drinks

The setup for conducting an experiment is that a neurophysiological reaction response takes place in the tested participants when they sip a drink. We have prepared the following toolset and methodology for the purpose of the experiment.

Initially, the following procedure is carried out for each respondent:

1. Step. Sip from a glass of test drink 1 without knowing the contents

2. Step.Wait approximately 10 seconds

3. Step. Sip water (Bankya)

4. Step. Drinks test drink 2 without knowing the contents

5. Step. Sip water (Bankya)

6. Step. Wait approximately 10 seconds

7. Step. Sipped test drink 3 without knowing the contents

8. Step. Wait approximately 10 seconds

9. Step. Sip water (Bankya)

We repeat these steps five times using the same procedure for data recording in order to obtain average result representation per test subject from the focus group. However, since the drinking process can cause signal artifacts, we analyze the recordings on intervals from two to seven seconds after the bottle is put back to the table, as shown in Figure 4.

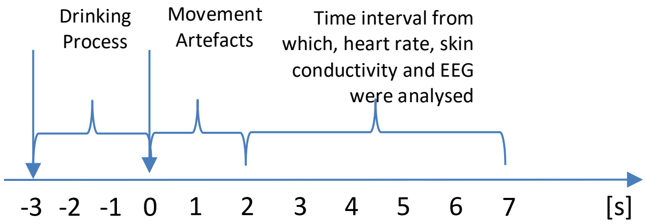


Fig. 4. Signals analysis time interval.

We have obtained the following averaged experimental data of the group for the 23 physiologic biometrics and feature parameters observed, as presented on the following Figures.

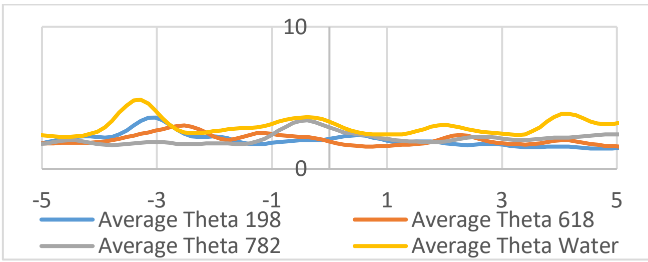


Fig. 5. Average forTheta frequency rangs [uV^2]

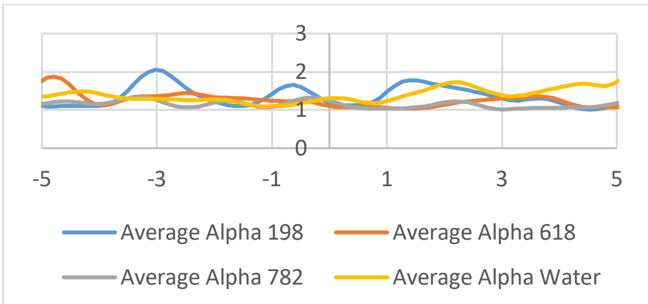


Fig. 6. Average forAlpha frequency rangs [uV^2]

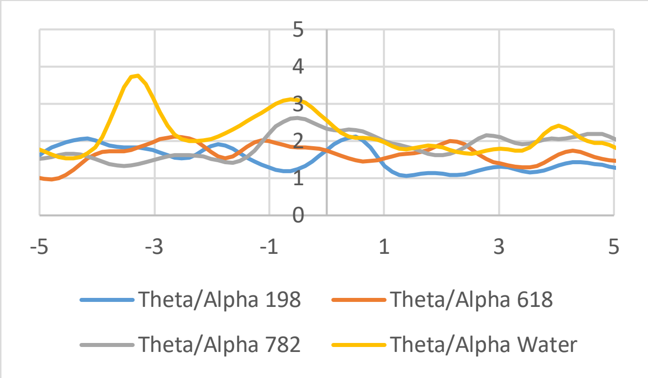
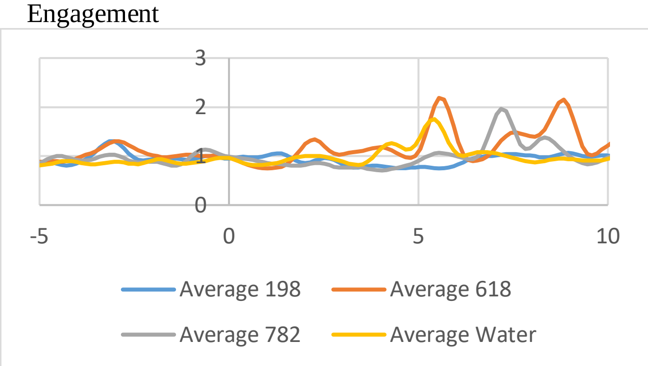
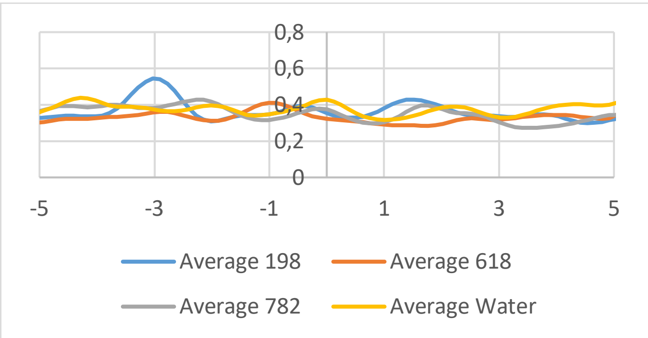


Fig. 7. Theta/Alpha Ratio

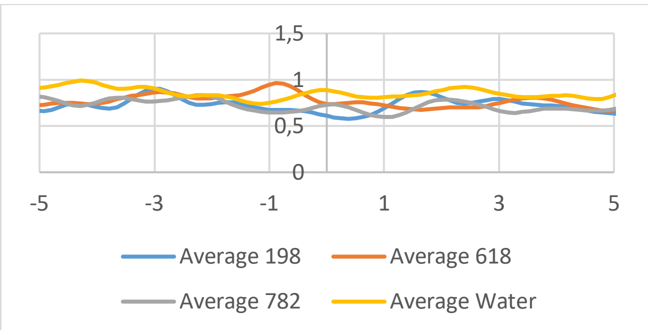
Engagement



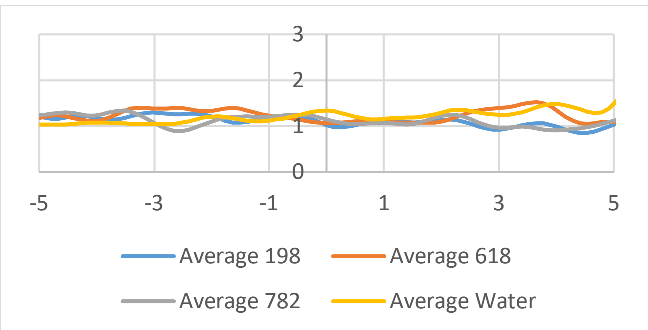
Excitement



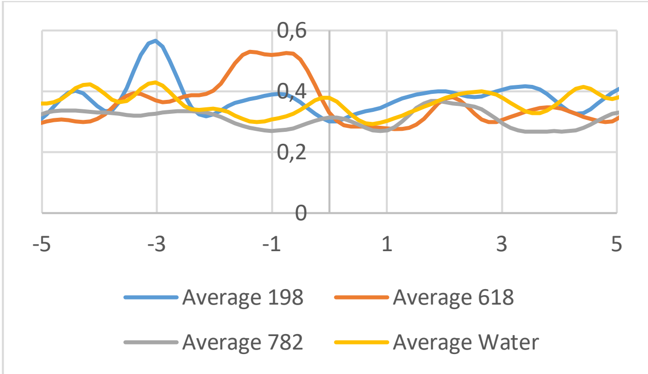
Focus



Interest



Relaxation



Stress

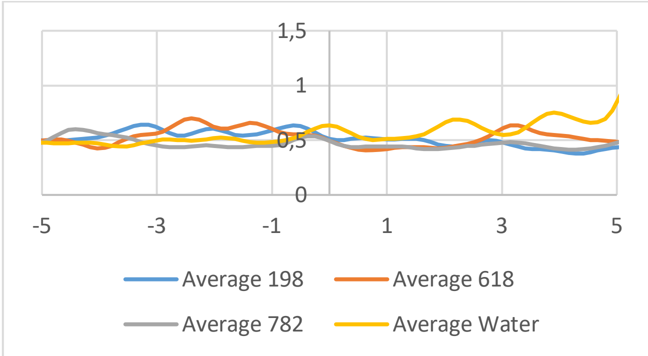


Fig. 8. Average values of the six measured emotional states for 11 subjects

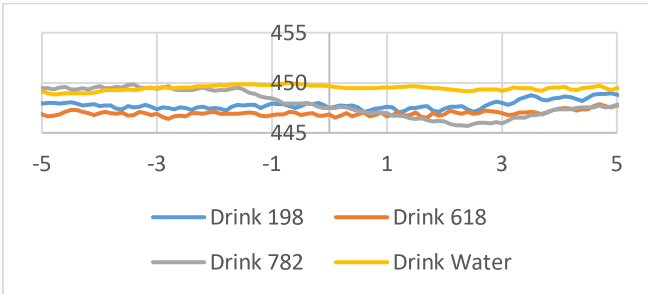


Fig. 9. Skin Conductivity

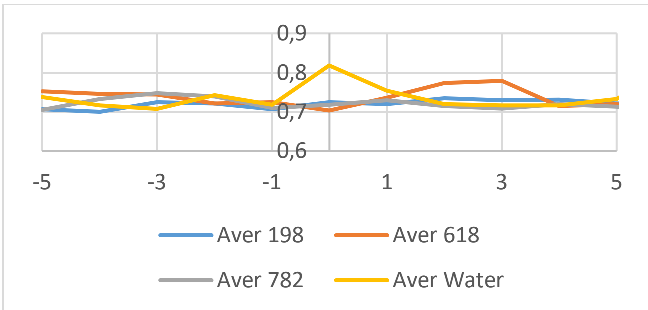


Fig. 10. Heart rate tracking (Pulse, HRI)

The test data set based on the EEG data, with aggregated data from the whole participants is given in Fig5, Fig.6 and Fig.7, while the informative features, that are obtained with EMOTIV's pretrained deep neural network, are presented on Fig.8 and the measured aggregated biometric data from the pulse rate and conductivity of the skin are given in Fig. 9 and Fig.10. The results show that there were no clearly statistically significant differences between the EEG power spectra in the Alpha and Theta frequency ranges when sipping the three test drinks and Bankya mineral water to make a clear and distant classification between each of the classes. Also, there were no clearly observable big statistically significant differences between the recorded data on heart rate, skin conductance and the six emotional states of the participants. This case that the test drinks produced almost identical stimulation in the respondents can be explained due to the fact that, the tested drinks are very similar, because it's a variety of the same taste flavor that was used.

Also, to conclude the experiment, each participant is interviewed in a semi-structured manner. On Table 1 are given the average scores that each separate brand achieves on each of the attributes from the sample of the participants of the test focus group. There, by combining the perceptual data with the test participant's responses on a scale of 1 to 10, preference shares were obtained and are presented in Table 1.

When further analyzing the data with the Distances between the studied drinks in two-dimensional space calculated on the basis of the observed 23 physiological parameters, we get the following results as shown on Fig.11.

	198	618	782	Water
198	0.000			
618	0.490	0.000		
782	0.461	0.096	0.000	
Water	1.328	1.326	1.361	0.000

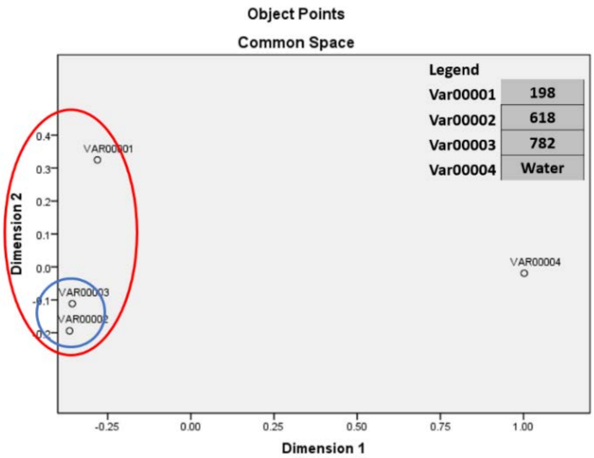


Fig. 11. Distances between the studied drinks in two-dimensional space calculated on the basis of 23 physiological parameters and visualisation of the resulting two-dimensional map with the four classes

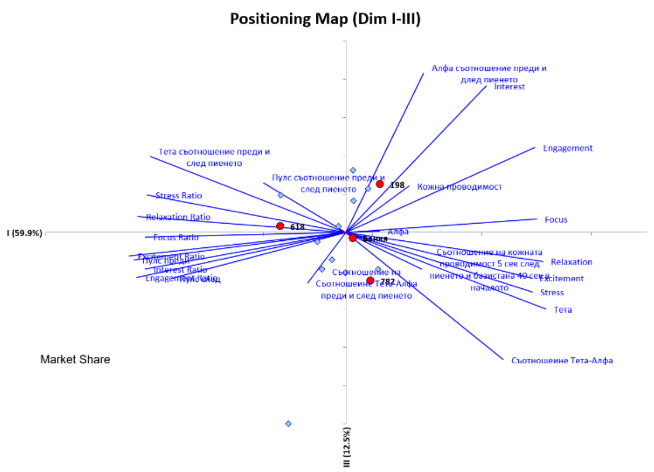


Fig. 12. A sample joint Positioning map of perceptions and preferences created from data on 23 physiological parameters (for Dim I-III)

TABLE I. PERCEPTUAL DATA - AVERAGE SCORE EACH BRAND ACHIEVES ON EACH ATTRIBUTE FROM RESPONDENTS SAMPLES.

Brands / Attributes	198	618	782	Water
Pulse before	**0.715072**	**0.782568**	**0.73012**	**0.748409**
Pulse after	**0.725813**	**0.786397**	**0.7527**	**0.717535**
Pulse ratio before and after drinking	**0.984739**	**1.008913**	**0.958372**	**1.042674**
Alpha frequency	**2.255036**	**1.81805**	**1.738441**	**5.935194**
Alpha frequency before and after drinking	**3.503676**	**1.445619**	**1.099407**	**0.895461**
Theta frequency	**3.575618**	**2.915133**	**3.899979**	**3.522306**
Theta frequency before and after drinking	**1.396375**	**1.917414**	**1.148716**	**1.266323**
Alpha-Theta ratio	**2.016642**	**1.820584**	**2.338825**	**2.03246**
Ratio of Alpha-Theta ratio before and after drinking	**0.879813**	**1.228672**	**1.092917**	**1.902759**
Skin conductance (Galvanic skin response)	**448.0358**	**447.1604**	**447.0819**	**449.5155**
Skin conductance ratio 5 sec after drinking and baseline at 40 sec at baseline	**1.027228**	**1.026067**	**1.027676**	**1.031834**
Engagement	**1.690283**	**1.412579**	**1.550328**	**1.509042**
Engagement Ratio	**0.921977**	**1.477466**	**1.113498**	**1.055659**
Excitement	**1.259021**	**0.91564**	**1.359969**	**1.032027**
Excitement Ratio	**1.032134**	**1.322736**	**1.096583**	**1.121013**
Focus	**1.636354**	**1.317064**	**1.59724**	**1.394702**
Focus Ratio	**1.079044**	**1.241746**	**1.105994**	**1.064572**
Interest	**2.363769**	**1.84723**	**1.904547**	**2.006547**
Interest Ratio	**0.968456**	**1.420578**	**1.119421**	**0.997556**
Relaxation	**1.058312**	**0.71422**	**1.106763**	**0.852036**
Relaxation Ratio	**1.097237**	**1.651298**	**1.113515**	**1.068201**
Stress	**0.891483**	**0.710554**	**0.966084**	**0.788596**
Stress Ratio	**1.197894**	**1.727672**	**1.134569**	**1.067268**

From the gathered data we observed that Drink 782 has the highest Preference of 62, Drink 618 is second with 58 and Drink 198 last with 57. This discrepancies were repeated again with the Preference mode as Drink 198 got 1, Drink 618 got 2 and Drink 782 got 3. Also a joint map of perceptions and preferences created from data on 23 physiological parameters was created. The Positioning maps were two dimensional representing Dim I-II, Dim II-III and Dim I-III, with some examples shown on Fig.12. From the Positioning maps and the remaining data we can have the conclusion that Drink 782 is the most preferable one and it was chosen as winning taste.

TABLE II. PREFERENCE DATA - PREFERENCE SCORE OBTAINED BY EACH BRAND FROM EACH RESPONDENT.

Brands / Respondents	Drink N:198	N:618	N:782	Water
Person1	6	2	1	0
Person2	5	6	8	0
Person3	8	9	7	0
Person4	5	5	5	0
Person5	7	5	4	0
Person6	5	6	8	0
Person7	2	1	1	0
Person8	4	5	6	0
Person9	4	7	6	0
Person10	5	4	7	0
Person11	5	7	8	0

Preference shares that are recovered by the model

Items / Preference Shares.	198	618	782	Water
Preference shares that are recovered by the model	29.91%	26.19%	27.98%	16.92%

The most preferred drink was linked with the lowest levels of stress, while the least preferred one was associated with highest similarity of its electroencephalography patterns to a stress state. The lowest rated drink in the classic interview scored the highest result on “interest” scale based on the electroencephalographic activity. It was found, that that more preferred drinks raised rate of heart by about 1 bpm in contrast to the less preferred ones. Respondents in the interviews reported that the sampled 782 type drink woke them up better than the other drinks, while others were very similar, being the same variant with different taste intensity. Since the test drinks produced almost identical stimulation in the respondents it is advisory that such tests to be conducted with drinks of higher taste difference and variety and with higher test focus groups.

IV. CONCLUSION

The objective of the research was to establish a reliable methodology for analyzing taste stimuli for neuromarketing applications. The study revealed that valuable insights can be gained from the bio-signals measured shortly after the introduction of the taste stimulus. Although the variations in response between different drinks were slight due to the testing drinks being very similar, they still provide valuable information for addressing common neuromarketing concerns, such as assessing the similarity in taste perception following the modification of a drink's chemical composition.

The research team was able to use biometric data to aggregate tastes and preferences to help a company choose more appealing product for a wider audience. It was demonstrated that that EEG activity in theta and alpha frequency bands, emotional states extracted for EEG trough neural network model approach, pulse rate, and skin conductivity can be used to evaluate taste perception. The emotional states of stress and interest obtained after analyzing EEG activity with Neural Network model, as well as heart rate, correlated most strongly with preferences determined by traditional methodology with questionnaires.

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