European Research Studies Journal
Volume XXIV, Issue 2B, 2021

pp. 1153-1162

Consumer Neuroscience – The Application of Selected Neurobiological Methods in Consumer Research

Submitted 28/03/21, 1st revision 25/04/21, 2nd revision 28/05/21, accepted 30/06/21

Barbara Wąsikowska[1]

Abstract:

Purpose: *The primary scientific goal of the article is to present the results of research on the application of neurobiology methods and techniques to analyze consumer behavior and test the effectiveness of advertising. During the study, respondent reactions (emotions, memory, or interest) to individual advertisement fragments were analyzed. Results of the neural and psychophysiological measurements were compared to participant responses obtained during direct interviews.*
Design/Methodology/Approach: *To achieve the aims of the article, the research was carried out in two stages. The first part was an experiment using electroencephalograph (EEG) and biometric techniques, such as electrodermal activity (EDA), electrocardiography (ECG), and heart rate (HR). The second section of the study was based on direct interviews with the respondents.*
Findings: *The growing number of advertising messages and the seemingly increasing chaos within this area have meant a clear need to search for means, forms, and contents that can reach the client. The application of neurobiological knowledge in marketing can better understand these processes, such as emotions, attention, memory, or decision making. Knowledge of how the brain reacts to various stimuli can increase the effectiveness of an advertised message.*
Practical Implications: *Using EEG in combination with biometric techniques (EDA, ECG, and HR), researchers can better understand how consumers make decisions that could lead to them making a purchase. Research of this type can enable companies to reduce losses associated with launching a product on the market that no one wants to buy and lead to more effective and exciting advertising (in the case of the consumer) for the goods to be sold.*
Originality/Value: *This research attempts to fill a gap in the literature on the subject. An experimental research approach to consumers may provide new knowledge about their expectations, desires, and purchasing behavior. The research presented in this article also provides knowledge on combining traditional marketing research (in this case, direct interview) with modern neurobiological methods and techniques.*

Keywords: *Consumer neurosience, electroencephalography (EEG), biometric methods, Electrodermal Activity (EDA), Electrocardiography (ECG), Heart Rate (HR).*
JEL classification: *D87, D91, M31, M37.*
Paper Type: *Research article.*
Acknowledgment: *The project was financed within the framework of a Minister of Science and Higher Education program entitled the "Regional Excellence Initiative" from 2019 – 2022; project number 001/RID/2018/19; with the financing of PLN 10,684,000.*

[1]*University of Szczecin, Institute of Economics and Finance, Poland,*
barbara.wasikowska@usz.edu.pl;

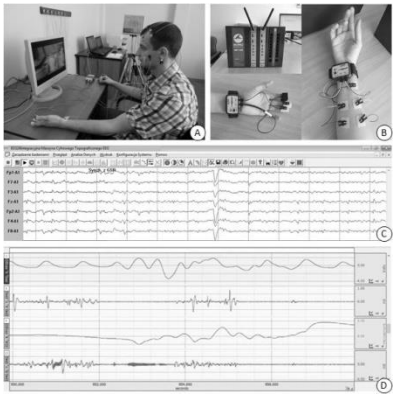
1. Introduction

Consumer neuroscience is a new, burgeoning field comprising academic research at the intersection of neuroscience, psychology, economics, decision theory, and marketing. Its main goal is to shed light on the fundamental questions of consumer behavior by coupling traditional, experimental, and statistical research techniques with those developed by neuroscientists (Plassmann, 2010).

Among the methods of neurobiology, the most frequently used in modern marketing research are electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) (Eun-Ju *et al.*, 2020; Rupali and Jaiteg, 2020; Vecchiato *et al.*, 2013). Using the EEG or fMRI methods in marketing research makes it possible to find out which advertising stimuli trigger a positive or negative emotional reaction. It is also possible to observe the degree of focus held on the subject's attention in real-time and how emotional involvement processes proceed in each second of the advertisement being viewed. Research using these methods also helps to identify the scenes which generate the most vital emotional involvement, illustrate reactions to the image, sound, spoken words, applying special effects, and can pinpoint the best version of background music that best strengthens the message contained in the image, as well as to choose the best way to display a logo or packaging, determine if the opening scene has the potential to make the advert stand out from the others and also decide which version of an ending will best inspire the viewer to buy the product.

Brain neuroimaging methods (e.g., EEG) are very often combined with biometric techniques, such as electrodermal activity (EDA), pulse plethysmography (PPG), and electromyography (EMG) (Figure 1). These methods allow the researcher to gain additional information about the psychophysical state of the respondent (Erdogan *et al.*, 2018).

Figure 1. *Registration of EEG, EDA, EMG, ECG and PPG signals while watching a movie with breaks for advertising (a, b) with sample recordings of the recorded signals (c, d)*



Source: *Own creation.*

The main scientific goal of the article to present the results of research on the use of

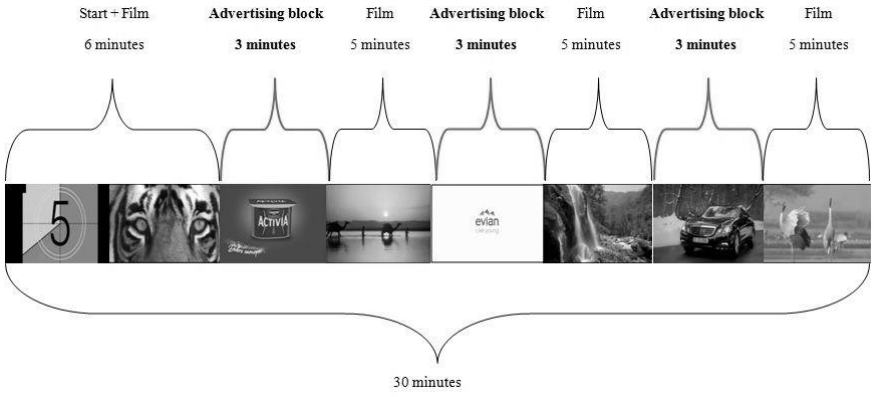
selected neurobiological methods and techniques to analyze consumer behavior and advertising effectiveness.

2. Literature Review

Forty-five healthy individuals participated in the experiment – students aged from 20 to 24. The relevant bioethics committee approved the study. The use of a 19-channel electroencephalograph recorded brain waves. Electrodes were attached to the scalp at seven points: Fp1, Fp2, F3, F4, F7, F8, and Fz (according to an international 10-20 system). A unipolar recording of brain electrical signals was then performed. The reference point was the left earlobe. Additionally, an ECG electrode was attached to the left wrist of each respondent, and 3 EDA electrodes were placed on the phalanges of fingers of the non-dominant hand to study electrodermal activity.

Each participant watched a half-hour documentary interrupted with three advertising breaks. The first break contained commercials for yogurt, the second - mineral water, and the third - - cars (Figure 2). Data was recorded both during the film and in the advertisements.

Figure 2. *Time division of the film into film fragments and advertising blocks*



Source: *Own creation.*

Immediately after finishing the central part of the study, the participants were asked to take part in a survey. The survey was conducted as a direct interview using an electronic questionnaire in the form of an Excel spreadsheet with pre-prepared questions. The first part of the interview consisted of demographic questions, and four further questions concerned the film. Demographic questions were aimed at collecting data relating to the demographic characteristics of the respondents, e.g., age and sex.

The second part of the interview consisted of questions concerning advertising breaks. The first question was connected with commercials aimed at detecting which of the

brands and products presented had been remembered by the participant (Q. 1. "You have just watched a film. During the projection you were shown some commercials (12 commercials in total). Do you remember the commercials you saw? Which commercials do you remember?"). The respondent's task was to enumerate brands and products they remembered when watching the film (if they did not remember any commercials, they had to proceed to question 3). Next, the researcher asked the respondents to give details regarding the plot of commercials they remembered, i.e., about people featured in the advertisements, places, props, or scenes featured in the commercial (Q. 2 "Can you say something about the plot of commercial A:"). The next stage was to check whether the respondent remembered the advertisement of a given brand and whether, while watching, they remembered seeing it before (Q. 3 "Did you see the advertisement for this brand while you were watching the film? When watching the film, do you recall seeing this advertisement before?"). For both of these questions, the respondent could answer "Yes" or "No." The entire study took 45 minutes.

3. Research Methodology

Electrocardiographic signal processing: The data analysis began with filtering signals with a band-pass filter, with an upper-frequency limit of 2 Hz and a lower frequency limit of 30 Hz. The recorded signal was then cleared of artifacts caused by eye blinks, eyeball movements, or any muscle tremor. An Independent Component Analysis (ICA) method was used for this task. After clearing the signals for each of the participants, the signals were transformed using a spatial filter known as CAR (Common Average Reference). Individual Alpha Frequency (IAF) was calculated for each participant; the application of this method is described in the literature (Klimesch, 1999) to establish the selected frequency bands. Next, the filtered EEG signals were used to calculate Global Field Power (GEP) (Lehmann and Skradnies, 1980). The values that were obtained were then used to determine the Pleasantness Index (PI), the Memorization Index (MI), and the Approach-Withdrawal Index (AWI) following scientific literature (Vecchiato *et al.,* 2013; Werkle-Bergner *et al.*, 2006):

$$PI = GFP_{right} - GFP_{left} \tag{1}$$

where the GFP_{right} and GFP_{left} stand for the GFP calculated among right (Fp2, F4) and left (Fp1, F3) electrodes, respectively.

$$AverageTheta_{left} = \frac{1}{N_Q}\sum_{i \in Q} X_{\theta i}^2(t), \tag{2}$$

where $X_{\theta i}(t)$ represents the i[th] EEG channel in the theta band recorded from the left frontal lobe. In addition, Q is the set of left channels (Fp1 and F3), N_Q represents its cardinality.

$$AWI = \frac{1}{N_P}\sum_{i\in P} X_{\propto i}^2 - (t)\frac{1}{N_Q}\sum_{i\in Q} Y_{\propto i}^2(t) = \quad (3)$$

$$= AveragePower_{\ \alpha\ right\ frontal\ lobe} - AveragePower_{\ \alpha\ left\ frontal\ lobe},$$

where $x_{\alpha i}$ and $y_{\alpha i}$ represent the i[th] EEG channel in the alpha band recorded from the right and left frontal lobes, respectively. In addition, P and Q are the sets of right channels and left channels, N_P and N_Q represent their cardinality.

An analysis of data obtained from the EEG was conducted by observing the brain asymmetry paradigm created by professor Richard Davidson from the University of Wisconsin-Madison (Davidson *et al.*, 1990; Davidson, 2004). According to this paradigm, an analysis of frontal and prefrontal lobe activity of the right and left brain hemispheres is carried out, and then a comparison of the results allows the researcher to interpret brain activity in a motivational context. If a participant is engaged and interested in what they see on the screen, the difference between the activity of their left and right lobes will be positive (i.e., the activity of the left hemisphere will be more substantial). However, when the participant is not interested in a film or advertisement, subtracting the activity of the right hemisphere from the activity of the left will be negative (Davidson, 1979). When both hemispheres are equally stimulated, neutral activity is said to be encountered (i.e., the respondent is neither interested nor disinterested). In 90% of cases, an increase in interest/involvement is accompanied by a positive emotional reaction (Though not in every case).

Electrodermal activity signal processing: In the study mentioned above, electrodermal activity (EDA) was measured through the use of the Féré method, with a constant voltage of 0.5 V. In order to analyze the recording of the galvanic skin response, a band-pass filter was employed with the lower frequency limit of 0.2 Hz (in order to separate the phasic components of the electrodermal activity from the tonic components), and the higher frequency limit of 1 Hz (in order to filter out the noise and to suppress artifacts caused by Ebbecke waves; Schmidt and Walach, 2000). Both the EDA signal and other signals were registered for the entire duration of the film. The registered signals were then divided into fragments (those recorded during the film were separated from the others recorded during the advertisements). The EDA signal was analyzed simultaneously with the respective EEG records. It was then possible to determine the kind of emotions that were evoked by given marketing communication.

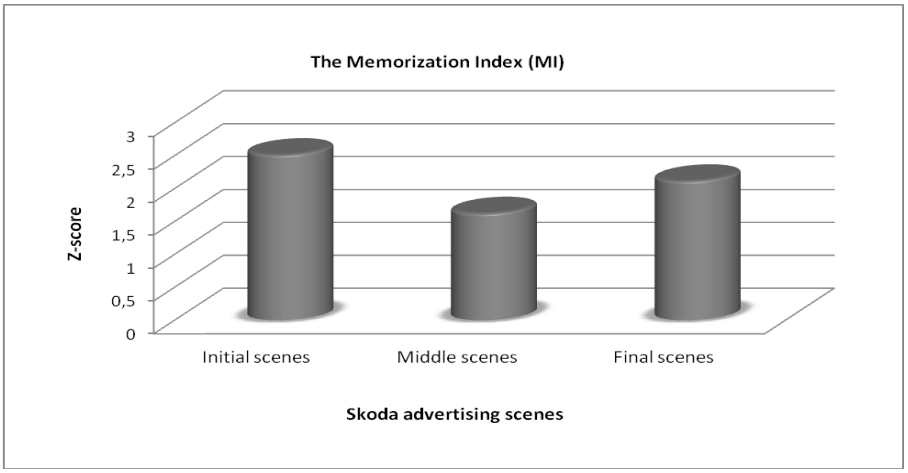
Electrocardiography signal processing. The registered ECG was processed in order to extract heart rate (HR) signals. HR signals were isolated by establishing a peak-to-peak distance on the ECG record (i.e., by calculating the interbeat interval – IBI – between successive heartbeats) and calculating the distance reverse. The HR record is additional (aside from EEG and EDA) information on any emotions experienced by the respondents during the film and advertisements.

The analysis of survey data: The second part of the study consisted of questions about advertising breaks. The respondent's answers, collected during the direct interview, were compared with the analysis of EEG, EDA, and ECG records. The purpose of this comparison was to find out how well a given advert was remembered and which scenes were liked and which not and why.

4. Results

Below we can see the results of an analysis based on the Skoda Rapid Backpack advertisement example. The scenes of this advertisement were divided into three groups: initial, middle, and final scenes. An analysis of the EEG record and the responses taken from the respondents during the direct interview shows that they remembered the Skoda advert quite well (Figure 3).

Figure 3. *The Memorization Index (MI) for the* Skoda *Rapid Spaceback advertisment*



Source: *Own creation.*

The advert begins with a car driving around a town. When the car passes by a woman walking her dog, it causes them to become weightless and begin to float (Figure 4c-e). The respondents remembered this scene particularly well. They especially liked the scene with the dog floating in the air (Figure 4d).

Figure 4. *Initial scenes of the Skoda Rapid Spaceback car commercial*

Source: *The author, taken from https://www.youtube.com/watch?v=YFLRyDl9YIc.*

The middle scenes of the advert were also well remembered by the respondents. However, they did not like the scene where the car heads straight towards the cyclist (Figure 5g-l). The negative PI value also confirmed this for this scene (Figure 6). Respondents believed that the cyclist was forced to make a dangerous jump over the car to avoid a collision.

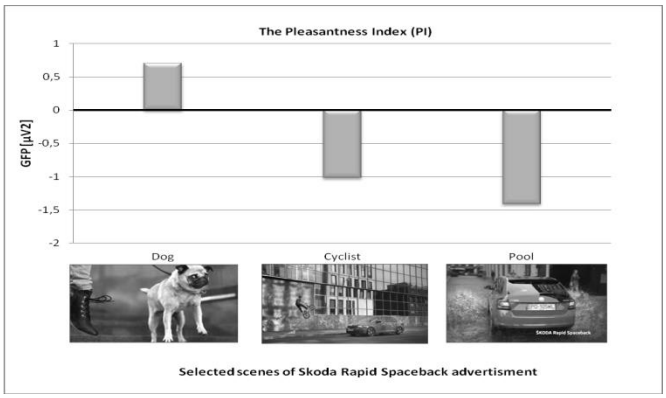
Figure 5. *The middle scenes of the Skoda Rapid Spaceback car commercial*

Source: *Own creation based on: https://www.youtube.com/watch?v=YFLRyDl9YIc.*

This was in contrast to the advertiser's intention, which was to show that the cyclist also floats into the air, just as the woman walking her dog had done earlier in the advert.

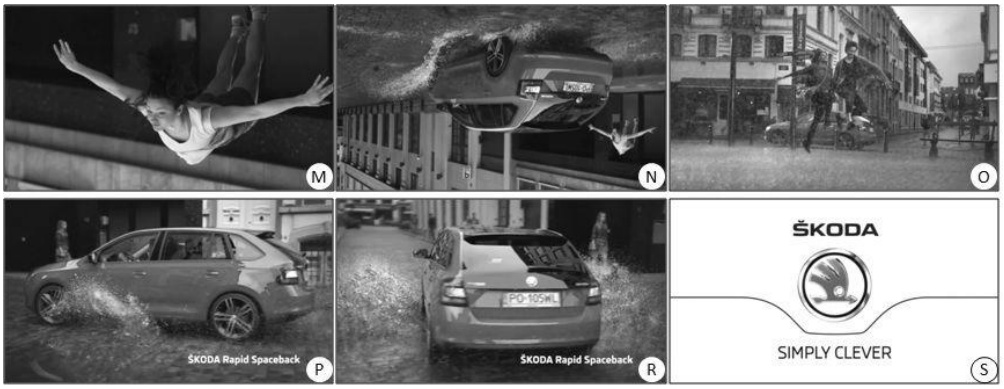
However, the least popular scenes among the respondents were the final scenes. Here, the Skoda Rapid Spaceback drives through a city during a rainstorm. When the car drives through puddles, it splashes water on the pedestrians (Figure 7).

Figure 6. *The Pleasantness Index (PI) for selected scenes of Skoda Rapid Spaceback advertisment*



Source: *Own creation.*

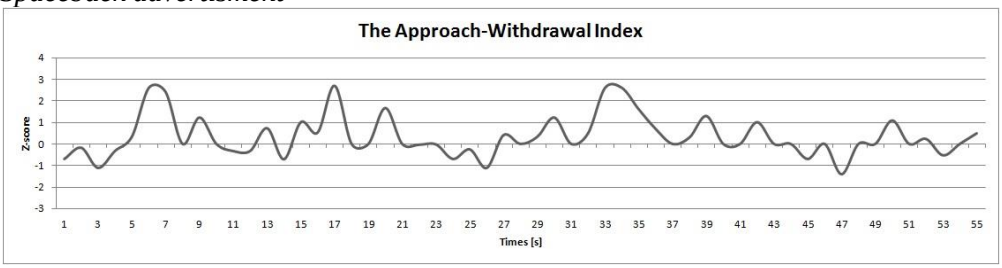
Figure 7. *The last scenes of the Skoda Rapid Spaceback car commercial*



Source: *The author, on the basis of https://www.youtube.com/watch?v=YFLRyDl9YIc.*

The Approach-Withdrawal Index (AWI) was also calculated for all of the Skoda advertising scenes (determined on the basis of formula 3). The AW signal of each subject was the *Z*-score transformed and then averaged to obtain an average waveform. This index indicates general level of respondent interest to the advert they saw. After analysing the AWI values it can be concluded that, generally, the advertising clearly did arouse the interest of the viewers (Figure 8).

Figure 8. *The Approach-Withdrawal Index (AWI) for the entire Skoda Rapid Spaceback advertisment*



Source: *Own creation.*

5. Conclusion

Modern marketing strategies require something more than just creating new products or services, offering attractive prices, or just making them available. Companies need to communicate with current and prospective clients. For most marketing specialists, the main issue is not whether to communicate but rather how, when, to whom, and how often. In order to reach target clients effectively and affect their shopping decisions, they apply various, creative forms of communication, including mass (non-personal) communication, whose essential instrument is advertising. Advertising remains one of the main elements of any marketing campaign. Even in today's very demanding media environment, good advertising can offer considerable benefits.

The study of communicative effectiveness, also known as the study of advertising contents, aims to determine whether a particular advertisement is effective. Marketing specialists should perform such studies both before and after the advertisement is placed in the media (Kotler and Keller, 2012). The study of advertising contents and their influence can be carried out through various research methods. This article presents one of the most modern approaches to studying advertising contents, i.e., via the application of electroencephalography (EEG).

The increasing number of messages and the ever-growing chaos in advertising means that companies are looking for media, form, and content that will reach the customer effectively. The application of neurobiological knowledge in the context of marketing can contribute to a greater understanding through these processes, such as emotions, attention, memory, and decision-making. Undoubtedly, these are critical goals for advertising and consumer behavior. Knowing how a viewer/customer's brain will react to various stimuli can increase the effectiveness of advertising communication.

References:

Davidson, R.J. 2004. What does the prefrontal cortex "do" in affect: perspectives on frontal EEG asymmetry research. Biological Psychology, 67(1-2), 219-33.

Davidson, R.J. Schwartz, G.E. Saron, C., Bennett, J., Goleman, D.J. 1979. Frontal versus parietal EEG asymmetry during positive and negative affect. Psychophysiology, 16, 202-203.

Davidson, R.J., Ekman, P., Saron, C.D., Senulis, J.A. Friesen, W.V. 1990. Approach-withdrawal and cerebral asymmetry: Emotional expression and brain physiology. Journal of Personality and Social Psychology, 58, 2, 330-341.

Erdogan, K., Hakan, B. 2018. Chapter 5 - How Can Consumer Science Be Used for Gaining Information About Consumers and the Market? The role of psychophysiological and neuromarketing research. Case Studies in the Traditional Food Sector. A volume in the Consumer Science and Strategic Marketing series, Woodhead Publishing Series in Food Science. Technology and Nutrition, 129-152. DOI: 10.1016/B978-0-08-101007-5.00013-0.

Eun-Ju, L., Hanah, C., Jinghe, H., Dong Hyun, K., Eunju, K., Kyung Hoon, K. 2020. How to "Nudge" your consumers toward sustainable fashion consumption: An fMRI investigation. Journal of Business Research, 117, 642-651. DOI: 10.1016/j.jbusres.2019.09.050.

Klimesch, W. 1999. EEG alpha and theta oscillations reflecy cognitive and memory perfomance: a review and analysis. Brain Research, 29(2), 169-195.

Kotler, P., Keller, K.L. 2012. Marketing management (14th ed.). Prentice Hall, Upper Saddle River, New York.

Lehmann, D., Skrandies, W. 1980. Reference-free identification of components of checkerboard-evoked multichannel potential fields. Electroencephalography and Clinical Neurophysiology, 48, 609-621.

Plassmann, H., Yoon, C., Fred, M., Feinberg, F., Baba, S. 2010. Wiley International Encyclopedia of Marketing, Part 3. Consumer Behaviour. DOI: 10.1002/9781444316568.wiem03051, Wiley Online Library.

Rupali, G., Jaiteg, S. 2020. A study of neuromarketing techniques for proposing cost effective information driven framework for decision making. Materials Today: Proceedings. In Press, Corrected Proof. DOI: 10.1016/j.matpr.2020.08.730.

Schmidt, S., Walach, H. 2000. Electrodermal Activity (EDA). State of the art measurement and techniques for parapsychological purpose. Journal Parapsychol, 64, 139-163.

Vecchiato, G., Cherubino, P., Trettel, A., Babiloni, F. 2013. Neuroelectrical Brain Imaging Tools for the Study of the Efficacy of TV Advertising Stimuli and Their Application to Neuromarketing. Biosystems & Biorobotics. Springer.

Werkle-Bergner, M., Muller, V., Li, S.C., Lindenberger, U. 2006. Cortical EEG correlates of successful memory encoding: implications for lifespan comparisons. Neuroscience and Biobehavioral Reviews, 30(6), 839-854.