**Progress in Agricultural Engineering Sciences** 21 (2025) 1, 215–231
DOI: 10.1556/446.2025.00162

# What our skin says about ads: Evaluating emotional reactions through GSR

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ORIGINAL RESEARCH PAPER

Received: December 19, 2024 • Accepted: July 8, 2025
Published online: August 12, 2025


## ABSTRACT

To determine whether stimuli, such as advertisements, evoke the intended emotional response, emotion measurement tools are essential. Among these, Galvanic Skin Response (GSR) is a reliable physiological indicator that reflects changes in skin conductivity, linked to the parasympathetic nervous system. In this study, GSR sensors were used to assess emotional reactions triggered by advertisements with diverse themes. Data collected from 44 participants, resulting in 51,000 data points, underwent cluster analysis, which grouped responses into homogeneous categories. Linear discriminant analysis (LDA) further demonstrated that different advertisements elicited distinct emotional responses, highlighting their varying effectiveness. While the method effectively measured emotional intensity and structural impact, additional refinement is required to pinpoint the specific direction of emotions. This research underscores the value of GSR as an objective emotional measurement tool in advertising, offering insights for optimizing marketing strategies and enhancing consumer engagement.

## KEYWORDS

brain arousal, media, sensory, digital sensory, marketing

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## INTRODUCTION

The 21st century is characterized by a hurried, time-concentrated lifestyle. One disadvantage of today's fast-paced lifestyle is that the human body is exposed to an increasing variety of stimuli, only some of which manage to penetrate consciousness—typically those with distinctive features or unique characteristics. Consequently, it presents a significant challenge for marketers to create materials (especially advertisements shown to consumers) that effectively convey all the benefits of a product or service in an informal way while also motivating the consumer to make a purchase (Fernández-Escobar et al., 2021; Johnson et al., 2013). Due to human nature, such stimuli have an individual impact and can evoke emotions, yet similarities in the "polarity" of these emotional responses are often observed. It is not uncommon for the same phenomenon or stimulus to provoke joy and laughter in one person, while another responds with surprise or negative emotions (Herring et al., 2011). The effects of advertising can be derived from five factors:

- information from advertising (relevance, price, product features),
- emotions (positive/negative),
- the structure of the advertisement (length, vocalization of the speakers, size of the logos placed, simplicity of the advertisement),
- special effects (humor, music, other phenomena),
- demographic factors of the viewers (gender, age, socio-cultural values, social financial position (Amiri et al., 2022).

These are measured by the discipline of neuromarketing, which is most defined as "a multidisciplinary science for the profitable satisfaction of consumer needs, based on the concept that the consumer's unknown needs are inferred from the physical reactions and involuntary neural responses of the consumer to himself or herself" (Agarwal and Dutta, 2015). In the history of the development of the discipline, several measurement designs have emerged, one of the most original of which is the completion of questionnaires (Pereira et al., 2022; Quiles Pérez et al., 2024). They have the advantage of being able to assess a relatively wide range of emotional responses quickly, but their disadvantage is that it relies on the participants' ability to express their emotions (Jaeger and Cardello, 2016), and social desirability bias (Krumpal, 2013), etc. These can be overcame by the use of a number of measurement set-ups and instruments that determine objective physical properties, the most common of which are electroencephalographic measurement, galvanic skin response, eye-tracking, and procedures for monitoring the activity of facial muscles (Eisenstein et al., 1990; Mena et al., 2023; Rodrigues et al., 2024 Szakál et al., 2023). Current and future areas of development in the discipline include the actual and simulation of changes in various measurement (physical) environments (e.g. microgravity, Augmented Virtuality, Augmented Reality, Virtual Reality environments) (Kakaria et al., 2023; Zulkarnain et al., 2024).

Rapid changes in skin conductance, which are controlled by the autonomic nervous system, happen spontaneously and without conscious awareness or control, in contrast to other techniques of assessing emotion. People can control their facial expressions or their gaze, but they are unable to control the functioning of their sweat glands. This makes Galvanic Skin Response (GSR) a useful technique since it can monitor brain activity (brain arousal) levels without depending on verbal communication or the possibility that people will hide their actual feelings

(Albert and Tullis, 2023). GSR involves the conductivity evolution of a secretion produced by sweat glands in human skin tissue (especially in the *stratum corneum*), which contains predominantly metallic ions ($Na^{+}$, $Cl^{-}$, $K^{+}$, $Ca^{2+}$, $Mg^{+}$) in the form of salts (Critchley, 2002; Lee et al., 2022; Wake et al., 2016). The phenomenon is described by the change in resistance caused by the change in electrode potential due to the flow of sweat gland current through the semipermeable membrane of the cells (Plate, 2016). Of course, in addition to the fact that sweating is influenced by environmental conditions (such as changes in ambient temperature, current physical activity, etc.), cognitive actions can often cause changes in skin resistance (e.g., brain activity, relaxation) (Geršak et al., 2012; Kahneman et al., 1969; Wake et al., 2016).

There are many devices available on the market with different product specifications, but one of the most common is the Shimmer® (Shimmer, Dublin, Ireland) device called 3+ GSR. The measurement of skin resistance may vary, but nowadays, for the reasons described above, portable devices with finger-mounted electrodes are preferred, while skin resistance measurements are also known to be performed on other body areas, such as the back and earlobe (Amano et al., 2017). As an incoming physical signal (for which the device uses silver or silver chloride electrodes), GSR can be described with two trends: the slowly, gradually increasing signal is called in the literature skin conductance level (SCL), while the rapidly increasing signal is called skin conductance response (SCR). The former value provides information on the overall brain activity, while the latter provides information on the response to the pulse (Geršak and Drnovšek, 2020). The physiological response is expressed as conductance [μS] on the measuring devices, considering the minimum time-signal delay [μs] that occurs on electrodes, placed on the same dermatome, with at least 1 $cm^2$ surface area (Bulagang et al., 2020). The GSR+ Unit includes a 3.5 mm jack for interfacing with external devices, such as analog or digital sensors, from which the user may wish to measure data from other sources (e.g. hearth rate monitoring, electromyography sensors).

The placement of these electrodes can vary: for instance, they are often attached to the palm, wrist, back, or face. When selecting the sensor location, it is important to ensure that the placement does not cause discomfort or disruption for the participant, and that it allows for continuous data acquisition without sensor displacement (Sanches-Comas et al., 2021; Jo et al., 2021).

The device also offers the function called Auto-Range, which will set the range to the most suitable value to the current reading, based on pre-determined transition points. This does not have any effect on GSR data because the frequency range of interest for GSR is much lower than the auto-range settling frequency. For data recording, the tool uses "EEPROM" memory, what means it has 2 GB working resource to do the calculation with each electrode between the skin resistance (measured) to skin conductance (calculated) with the following formulas:

$$R_s = \frac{R_f}{\frac{ADC\ Value * \left(\frac{3\ V}{4096}\right)}{0.5\ V} - 1} \quad [1]$$

where

$\boldsymbol{R_s}$ is the measured value of skin resistance in Ω,
$\boldsymbol{R_f}$ is the value of the feedback resistor, in Ω, used by the sensor for a given range
***ADC Value*** is the 16-bit output of the ADC (i.e., uncalibrated GSR value).

$\frac{3\,V}{4096}$ is the voltage per bit of the ADC, where the reference voltage of the ADC is 3.0 V and the 12-bit ADC has 4,096 different measurement levels.
$\mathbf{0.5}\ \boldsymbol{V}$ is the reference voltage used by the sensor (Shimmer, 2018)

$$G = \frac{1}{Rs} \tag{2}$$

where

$\boldsymbol{G}$ is for skin conductance in S,
$\boldsymbol{R_s}$ the measured value of skin resistance in Ω (Shimmer, 2018).

The advantages of using the previously mentioned tool are the portability, the large number of different sensors that can be connected, the high data acquisition rate and sensitivity, the variety of measured signals, the computational background supporting the software evaluation (storing data with SD cards, communication with wired (hotspot)/wireless (Bluetooth connection), and the adaptability to other signal processing applications (including the present experimental design). The primary use of GSR has linked to in polygraph examinations in the field of justice to identify whether several suspects are lying (given that the degree of GSR in a polygraph varies with sweating) (Steinbrook, 2010). Other everyday applications of the GSR include the detection of everyday traffic stimulation, which has shown that people who use public transport tend to have higher skin resistance and are therefore more sensitive to different environmental stimuli than those who cycle or drive (Yang et al., 2021). Luckily, this method can easily connect to other instruments, for example Electric Nose (for measuring and predicting academic stress levels under exams, Durán Acevedo et al., 2021), facial expressions with analytical tools (FaceReader, Baranda et al., 2024). The GSR also useable for sensory perception and therapeutic implications for managing dry mouth and swallowing disorders (Picó Munyoz et al., 2024) and measuring effectiveness of advertising touristic sights (Guerrero-Rodríguez et al., 2020) Furthermore, GSR has applications in neuropsychological studies to understand emotional engagement, improving user interface design by monitoring stress responses, tracking physical fatigue in athletes, and aiding in virtual reality-based therapeutic settings to create adaptive experiences based on user brain activity levels (Morrone and Minini, 2023; Gao et al., 2025).

A measurement and workflow design was conducted to explore the application of skin resistance changein advertising and. The study investigates whether participants can be grouped based on their GSR scores using the applied measurement design. An additional aim was to determine whether advertisements could be clearly separated using the measurement design. This study proposes a novel use of Galvanic Skin Response (GSR) to assess emotional arousal and distinguish between different advertising strategies.

## MATERIALS AND METHODS

For the experiment, 9 English-language commercials of a total length of 408 s were selected, the order of which was predetermined. The sequence was designed to alternate videos with somewhat contrasting moods to allow for the detection of perceived fluctuations. In addition, it has been considered that the commercials should not be too long (to avoid fatigue).

To recruit participants, participants of different genders, nationalities and ages were invited who had English language proficiency and interested in this field of research. Participants were selected to ensure diverse representation in terms of age, gender, and cultural background, enhancing the generalizability of the findings. Verbal consent was obtained using the statement: *"I am aware that my responses are confidential and I agree to participate in this experiment*", where an affirmative reply was required to participate in the experiment. They could withdraw from the experiment at any time without giving a reason. Ethical approval was obtained from the MATE internal ethics committee (approval number: MATE-BC/103-1/2025).

A total of 44 individuals participated in the experiment (the majority were university students and academics), as detailed in Table 1. Most respondents come from Europe and Africa, representing 16 (36.4%) and 14 (31.8%) participants of the panelist respectively, followed by Asia with 11 participants (25%), South America with 2 participants (4.5%), and other regions with 1 participant (2.3%). European representation is primarily from Hungary and neighboring countries, while African candidates come from diverse nations such as Kenya, Ethiopia, and Ghana.

After being greeted, participants were asked to sit down in a comfortable armchair in an air-conditioned room (set to 24 °C) with a cold white light (7,000 K) and GSR sensors were attached to their earlobe, index and middle fingers.

For the data acquisition, a unit called 3+ GSR from Shimmer® (Shimmer, Dublin, Ireland) was used, while the measurement range for the experiment was set between 2 μS – 100 μS (conductance with ±10% error) and frequency range to 15.9 Hz. The electrodes were placed on the inner phalanges of the index and ring fingers of the hand—since these areas share the same dermatome—and on the earlobe, ensuring unobtrusive wear and continuous data acquisition.During the measurement, beside the GSR signals, eye movement data were also recorded, the Tobii® Pro Lab software (version 1.217, software package: Analyzer Edition, Tobii AB, Danderyd, Sweden) was used for data acquisition (the results of eye-tracking measurements will not be presented in this study). Participants were also asked to perform an eye-tracking calibration (60 cm from the display with 9-point calibrational rectangle with 1024*1280 pixel image/picture size) (Drewes et al., 2019). Recordings were taken on weekdays (01/03/2023 – 15/03/2023), between 10:00 and 15:00.

*Table 1.* Distribution of participants ($N = 44$)

| Gender | Number of participants | Age (mean ± standard deviation) [years] | Region |
|---|---|---|---|
| Female | 23 | 25.36 ± 3.39 | Europe: 8<br>Africa: 5<br>Asia: 7<br>South America: 2<br>Others: 1 |
| Male | 21 | 26.95 ± 3.01 | Europe: 8<br>Africa: 9<br>Asia: 4<br>South Africa: 0<br>Others: 0 |

Own source.

After a successful eye-tracking calibration, the participants watched the commercials without interruption, wearing headphones. During the viewing of the recordings, any distracting external factors (such as movement in the room, conversation, other interaction) were minimized, thus creating a sense of calm for the participants and helping to increase efficiency. The videos are available at the following hyperlink: https://www.youtube.com/watch?v=t89AZA5uwbQ. The advertisements have been assigned labels from “A” to “I” in this study. These identifiers consistently represent the same advertisement.

Following the video compilation, participants completed a demographic and psychographic questionnaire. This included open and closed questions designed to explore prior advertising knowledge and advertising liking and to look for correlations between responses to these questions.

The questions were formulated as follows:

- *Participant’s gender*
- *Participant’s age*
- *Participant’s nationality (write down your nationality or your country)*
- *Which brands do you remember from the video? Please list all of them!*
- *Rate the commercials from –3 to +3! (–3 is the saddest, 0 is neutral, +3 funniest video)*

The GSR data series (timestamps and conductivity) were extracted from the Tobii® Pro Lab (version 1.217, software package: Analyzer Edition, Tobii AB, Danderyd, Sweden) application and processed using Microsoft Excel® (version 2309, software package: Office 16 (Microsoft, Redmond, Washington, USA)) software. The data filtering was done due to the high number of data point (capture rate of around 125 data points per second, generation of nearly 51,000 data pairs from one measurement). In addition, all the relevant prerequisite tests (such as normality test, homogeneity of variance, multicollinearity, Barlett’s test of sphericity (for proving that the variance-covariance matrix is a good representation of the data, Dutilleul, 2007), Kaiser–Meyer–Olkin (KMO) index (evaluating sampling adequacy for factor analysis)) have been completed RProject® (version 4.2.1., R Foundation for Statistical Computing, Vienna, Austria) was used for further analysis of the data series. To explore patterns in the data series (participants’ GSR signals), linear detrending was performed to remove the bias introduced by the monotonic increase of GSR values over time. This time-related trend was addressed using *zoo* package (version: 1.8-14. (Zeileis and Grothendieck, 2005)) by fitting a linear regression model to each time series and subtracting the fitted values from the original GSR signals, thereby conducting the analysis on the residuals. To enhance interpretability, the data were subsequently aggregated: only those time points where all participants exhibited non-zero GSR responses were included, and these values were averaged over 0.75-s intervals. Following detrending, Linear Discriminant Analysis (LDA) was performed on the processed data using package *ggfortify* (version 0.4.16.) and *ggplot2* (version 3.4.0.) (Tang et al., 2016; Wickham, 2016) as well as the package *MASS* (version: 7.3-57; Venables and Ripley, 2002) in order to determine the discriminability of the advertisements based on GSR data. Participants were clustered into groups using cluster analysis (CA) with package *cluster* (version 2.1.3.) (Maechler et al., 2023 Agglomerative Hierarchical Clustering was applied for objective clustering, using Ward’s method based on Euclidean distances, which minimizes the sum of squares of internal variances within clusters (Fülöp, 2006; Gere, 2023). Cluster analysis was conducted on the LDA scores, revealing distinct participant groups characterized by unique behavioral and physiological response patterns.

In summary, the data analysis process is presented in Fig. 1.


*Fig. 1.* Graphical summary of the evaluation method (own source)

## RESULTS

Participants' prior advertising knowledge and advertisement evaluation are shown in Figs 2 and 3. Figure 2 represents that many of the participants had not actually seen the advertisements before the experiment or, if they had, they did not realize the brand even after watching the video. Figure 3 clearly shows that of all the commercials, most ratings were neutral or slightly positive, i.e. the commercials were generally found to be acceptable or moderately funny, but few

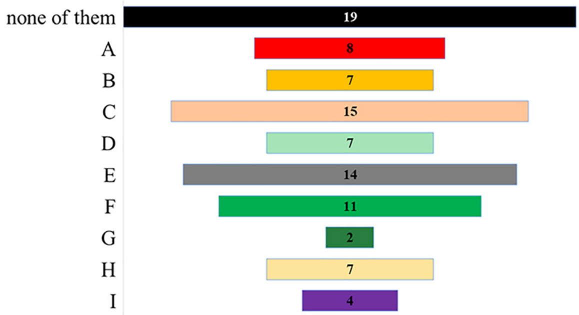


*Fig. 2.* Prior knowledge of the advertisements shown ($N = 44$) (own source)

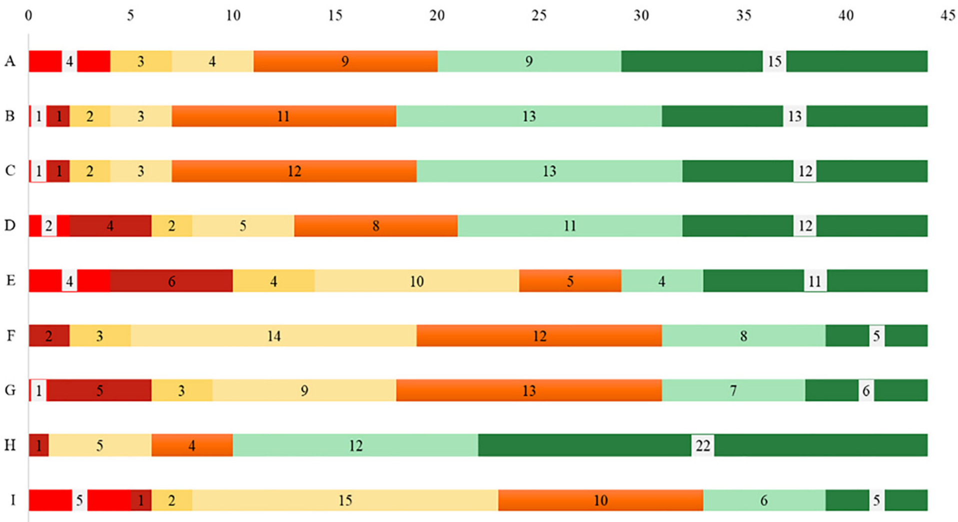


*Fig. 3.* Perceived humor of commercials ($N = 44$). The scale ranges from $-3$ to $+3$, with reddish shades indicating lower, yellowish neutral, and greenish shades indicating higher perceived humor (own source) (For colour figures see the online version)

commercials reached the outstanding (+3) level of funniness. The best ratings were given to those advertisements where something absurd (such as making excuses for an action) or unexpected phenomena and actions occur. At the same time, participants remembered advertisements that were more serious in tone or harder to understand.

In the Linear Discriminant Analysis, shown in Fig. 4, the discriminant functions were calculated directly from the detrended GSR data. This preprocessing improved class separability, revealing that the observed differences between advertisements are rooted in genuine variations in viewers' physiological responses, rather than in artifacts of the presentation sequence. The two discriminant variables—Discriminant Function 1 (Df1) and Discriminant Function 2 (Df2)—enable a clear distinction between advertisements. Df1 captures the overall separation between ad types, suggesting distinct autonomic activation patterns, while Df2 may reflect

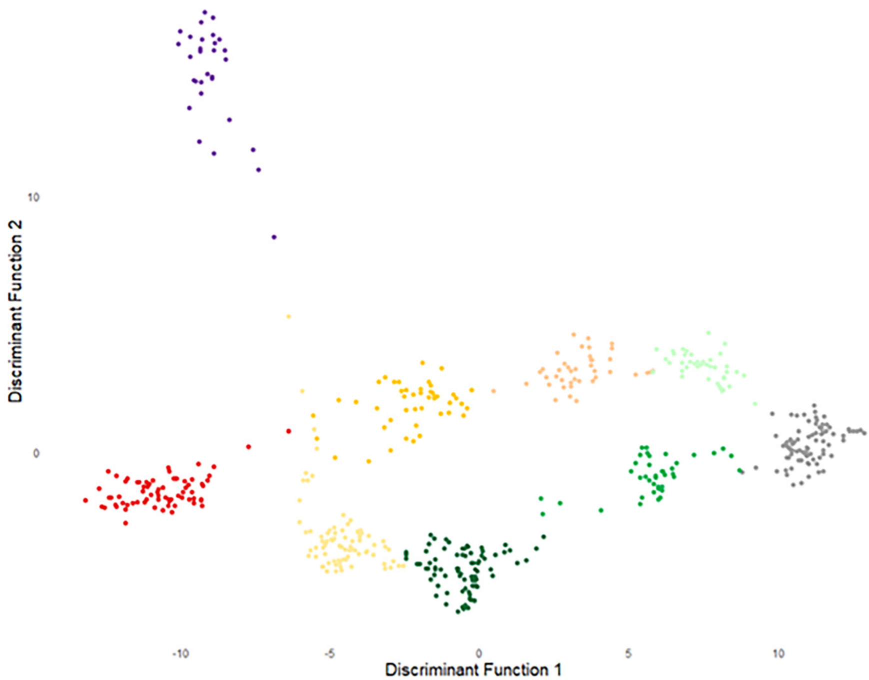


*Fig. 4.* Advertisement separation based on detrended and PCA-aggregated GSR data along discriminant variables (Discriminant Function 1; Discriminant Function 2) ($N = 44$).
Discriminant Function 1 illustrates the physiological separability of the commercials, while Discriminant Function 2 reflects dynamic mood-related variation in viewer responses (own source) (For colour figures see the online version)

complementary dimensions such as affective tone, expressiveness, or narrative dynamics. The resulting structure supports the interpretation that electrodermal activity can meaningfully differentiate advertisements based on both emotional and cognitive impact.

The result of the cluster analysis is shown in Fig. 5, which allowed the creation of clusters with varying quantitative composition. The formation of clusters (which were calculated from the LDA scores) was also supported by the eye-camera activities. The observed differences between clusters underline the importance of tailoring advertisements to diverse audience profiles.

The demographic distribution of each cluster is shown in Table 2. As can be interpreted, average age of the participants was 25.72 ± 0.88 years.

Figure 6(A–D) shows the average skin conductivity GSR graphs of the clustered participants. Figures show that the members of Cluster I. were more sensitive, with an order of magnitude larger GSR variation than the other clusters, while Cluster III and Cluster IV had more peaks, so they were involved as well. In the figures, the curves are plotted as the difference between successive data points, that results in negative datapoints.

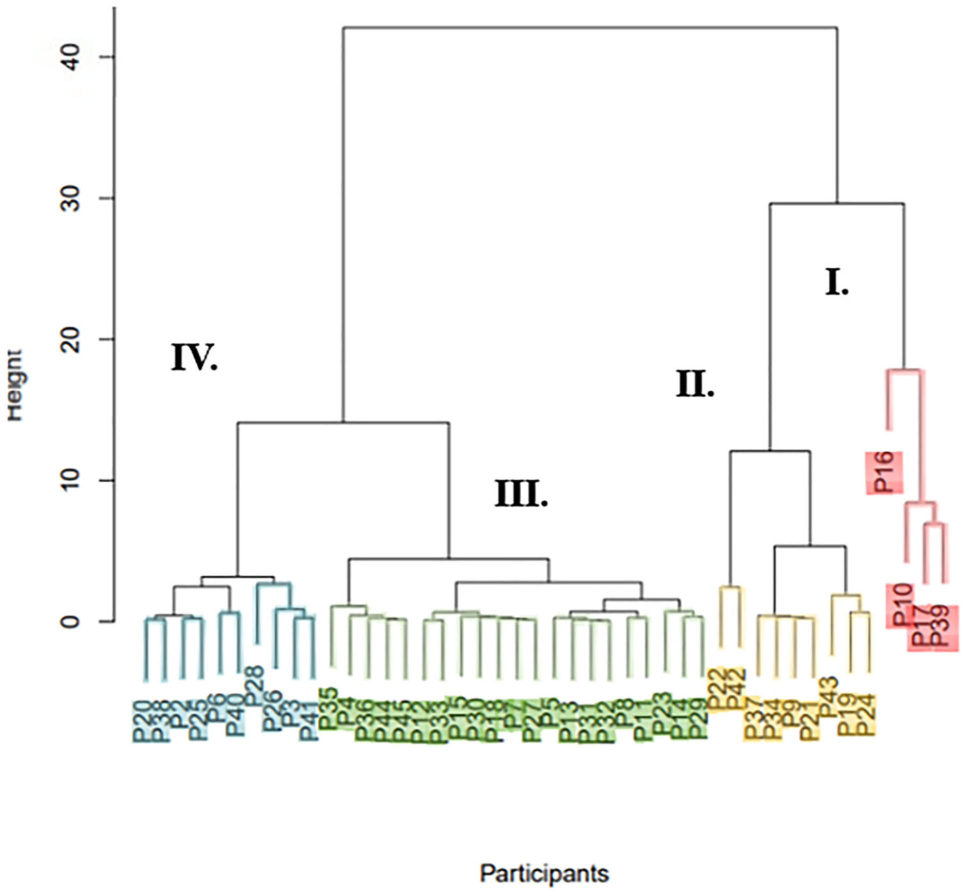


*Fig. 5.* Cluster analysis dendrogram ($N$ = 44) (X axis: Participants; Y axis: Height)
Cluster analysis identifies groups that show differences based on the Linear Discriminant Analysis Scores e.g., Cluster I to Cluster IV). The distances between the clusters on the dendrogram (height values) correspond to the magnitude of the differences (own source)

*Table 2.* Demographic distribution of Clusters I–IV

| Cluster identification | Number of participants | Number of female | Number of male | Age (mean ± standard deviation) [years] |
|---|---|---|---|---|
| I | 4 | 3 | 1 | 24 ± 3.13 |
| II | 9 | 4 | 5 | 24.67 ± 4.91 |
| III | 21 | 13 | 8 | 26.29 ± 4.89 |
| IV | 10 | 3 | 7 | 27.9 ± 4.87 |

Own source.

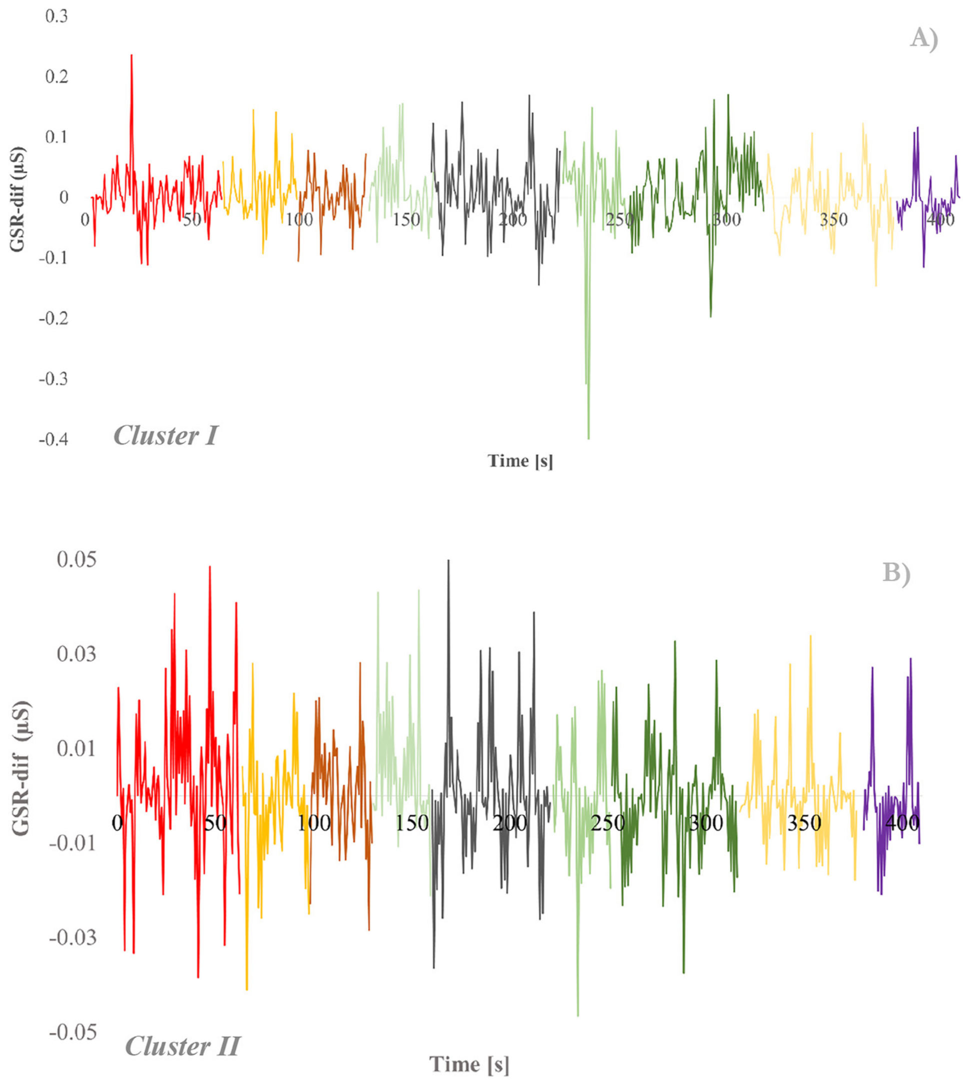


*Fig. 6.* Skin Conductivity- difference values by clusters. The curves are plotted as the difference between successive data points. A: Cluster I (4 participants), B: Cluster II (9 participants), C: Cluster III (21 participants), D: Cluster IV (10 participants).
The results in the advertisement are indicated by the following colors: **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H**, **I**
(own source) (For colour figures see the online version)

*(Figure 6 continued on next page)*

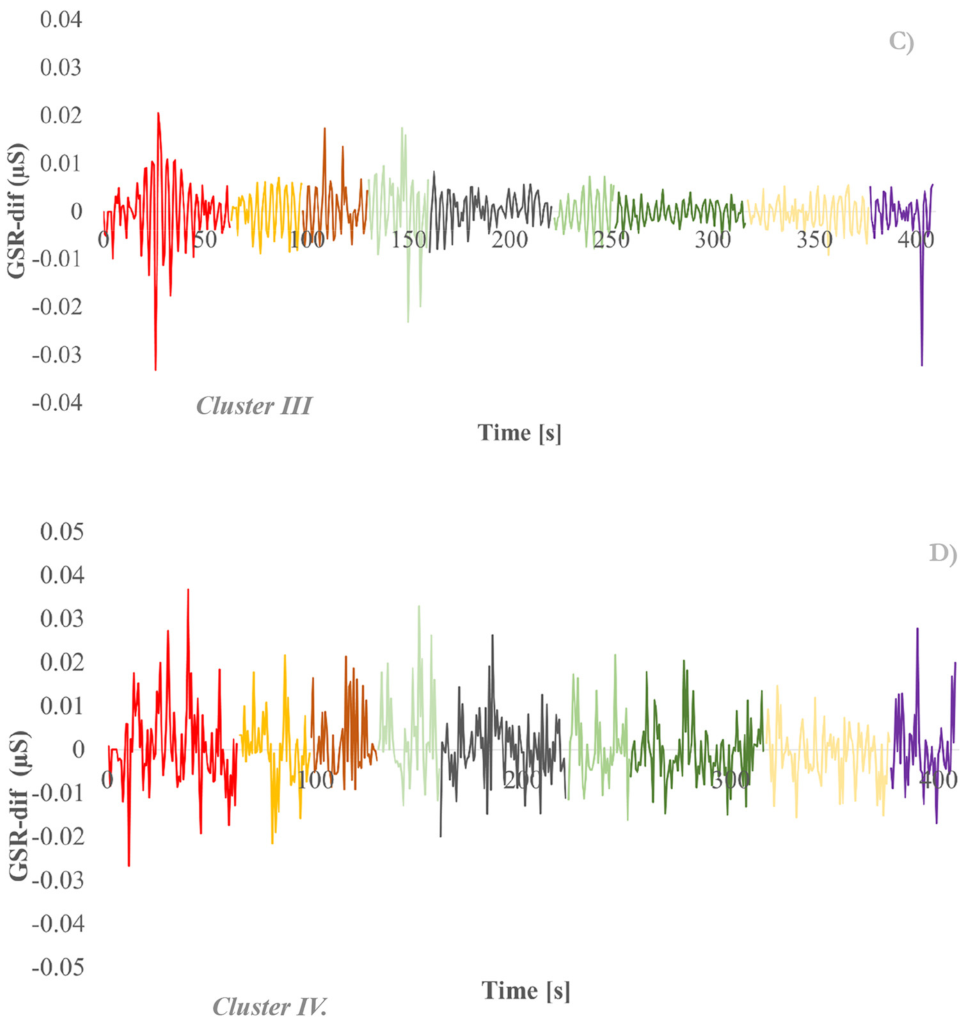


*Fig. 6.* Continued

## DISCUSSION

The measurement experiments were designed to include as many people of different nationalities and ages as possible, as the methods of effectively persuading people to use a product or service are different (Shahu, 2020). The results of the LDA (Fig. 4) indicate a fluctuation in advertising theme and mood: while the beginning and end of the advertising material was dominated by more light-hearted video material (reflected in the high Df2 values), the middle stage is dominated by more complex and serious advertising (low Df2 value), thus validating the importance of the advertising sequence design criteria as articulated in various literatures.

Cluster analysis from the participant data sets allowed the isolation of behavioral patterns of participants, which the GSR method used in the study were not always able to do. A further significant finding was the exploration of the effectiveness of discriminability based on linear discriminant analysis (LDA), which demonstrated the clear discriminability of advertisements based on GSR data. This is consistent with previous research by Kahneman et al. (1969), who also used changes in skin resistance to understand emotional responses. However, the present study went further by considering mood and structural differences in the advertisements.

As shown in Fig. 3, the perceived humour scores increase initially, decrease, and rise again toward the end, gradually decrease from a high initial score, then show a slight increase for the ads labelled "E" and "F", and finally a high steep spike for the advertisement labelled "H". The timing and style of the advertisement featuring the car brand may therefore be considered a key factor – although it was not the favourite –, in shaping the respondents' opinions. The latter can really be seen in Fig. 4, where the steepest rise is observed for this advertisement. It is worth noting that the sequence appears to have had an effect on the evolution of the responses, as previously established on the evolution) and participants' self-reported response, but care should be taken to draw a general conclusion from these, as we are still dealing with individuals that are different from each other (as in the case of advertisement labelled "I" many people considered it humorous, but this phenomenon does not show any outlier among the discriminant factors).

The findings indicated that GSR may be sufficient to identify differences between participants; however, the use of multiple instruments in parallel is recommended (i.e. fMRI, EEG, Pulse-meter, FaceReader), as they are not able to determine their sign (positive or negative emotion) (Vecchiato et al., 2010), while the variation in GSR values mapped the mood of the advertisements (high amplitude based peaks), which were caused by the thematic, visual illustration (special characters), sounds and other phenomena. However, it can be concluded that the prediction of emotions requires the involvement of additional tools, of which there are several good examples in neuromarketing (e.g. EEG, fMRI) (Colomer et al., 2014).

## CONCLUSION

Measuring the effectiveness of advertising using modern neuromarketing tool like Galvanic Skin Response (GSR) is a major step forward in understanding consumer behavior and emotional responses. The methodology used in the experiment allowed participants to be divided into homogeneous groups based on GSR data. The data allows for a more accurate inference of emotional change than previously possible with subjective questionnaires, and the use of these two techniques allows for targeted development of advertising materials and increases their effectiveness. The results of this type of research can be useful not only for the development of advertising materials, but also for broader applications such as product design, optimization of customer experience or the development of digital marketing strategies. The use of neuromarketing tools provides companies with the opportunity to better understand their consumers and to respond more effectively to their needs. To achieve this, it is essential to build on the demographic and psychographic characteristics of target groups. Research in this area should also pay close attention to representativeness.

Although various statistical analyses have shown good discriminability as advertisement designs based on some specific characteristics of the participants, the precise identification of the direction of emotional change remains limited, as GSR data do not clearly show whether the response is positive or negative. Therefore, the combined use of several tools that can also show the direction of emotions (such as FaceReader) should be encouraged in the future. Furthermore, the frequencies and filtering procedures used in the data analysis have affected the interpretability of the results, thus more in-depth statistical analyses are warranted for future research of this kind to develop appropriate data series.

## ACKNOWLEDGEMENTS

B.F.B thanks the support of the Doctoral School of Food Sciences, Hungarian University of Agriculture and Life Sciences. D.SZ. thanks, the support Doctoral School of Economic and Regional Sciences, Hungarian University of Agriculture and Life Sciences.

The authors thank the support of the National Research, Development, and Innovation Office of Hungary (OTKA, contracts No FK 137577).

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