Chapter 5

Measurement of Electrodermal Activity in Marketing Research

Sylwester Białowas, Adrianna Szyszka

Abstract: The paper presents the method of measuring electrodermal activity (EDA), its essential elements, assumptions related to the concept, and its possibilities in marketing research. The article also discusses examples of using EDA, together with other measurement methods. The aim of this chapter is also to present the methods of EDA measurement and to discuss the basic indicators and their interpretation.

Keywords: electrodermal activity, measurement, EDA, GSR, Galvanic Skin Response, marketing research, psychophysiological methods, consumer behaviour

Introduction

The subject of consumer research is the best possible understanding of consumer behaviour in response to specific stimuli. The existing methods of measuring such reactions, i.e. self-descriptive and behavioural methods, despite their undeniable advantages, also have their limitations. For this reason, psychophysiological methods have been used in marketing research in order to thoroughly examine the mechanisms of the human mind, taking into account the role of psychological processes. An unques-

Sylwester Białowas: Associate Professor at Department of Market Research and Services Management, Institute of Marketing, Poznan University of Economics, ORCID: <https://orcid.org/0000-0003-4575-5346>, sylwester.bialowas@ue.poznan.pl

Adrianna Szyszka: PhD Student at Department of Market Research and Services Management, Institute of Marketing, Poznan University of Economics, ORCID <https://orcid.org/0000-0002-1389-2365>, adrianna.szyszka@ue.poznan.pl

tionable advantage of psychophysiological methods is the fact that they enable the examination of such reactions of an individual that are not subject to its volitional control. One of these methods is the measurement of electrodermal activity as changes in the electrical properties of the skin are an autonomous reaction of the human body to the action of external stimuli. For this reason, the EDA measurement is also used in marketing as it allows us to examine consumer reactions concerning advertisements, products or trade fair stands. The purpose of this chapter is to present the EDA measurement and to determine its applicability in marketing research.

Electrodermal activity (EDA) – essence and a short history

Electrodermal activity (EDA) is considered as all electrical reactions generated by the skin and registered on its surface (Sosnowski, 1993). The term was first introduced in 1966 by Johnson and Lubin, but research in this field dates back to the 19th century (Boucsein, 2012). EDA is a measure of psychophysiological activity, which is an indicator of changes in the arousal of the sympathetic system. It is worth noting that it is the only psychophysiological parameter sensitive to changes in emotional states or cognitive activity, that is not affected by the activity of the parasympathetic system (Braithwaite, Watson, Jones, Rowe, 2013). Electrodermal activity is connected with the stimulation of the sympathetic system that operates during heightened alertness. This is accompanied by specific physiological reactions, such as sweat production, pupil enlargement or a change in breathing rate (Bell et al., 2018).

The first studies on electrodermal activity date back to 1879 when Vigoroux observed changes in the level of skin resistance while examining patients suffering from hysteria. The achievements of the French neurologist Charles Féré, who is considered a pioneer in galvanic skin reflex (GSR) research, were also particularly outstanding. In his research, Féré also focused on hysterical patients, noticing that a low current flow between two electrodes placed on the surface of the skin makes it possible to observe changes in resistance depending on the implied stimuli. Féré also pointed out that in the presence of an external stimulus, the skin becomes a better current conductor (Dawson, Schell, Filion, 2007; Neumann, Blanton, 1970). The physiologist Ivan Tarchanoff conducted his research on the electrical properties of the skin simultaneously, with a focus on the mechanisms behind the changes in skin conductance. Tarchanoff noticed that the electrodermal phenomena are determined by the activity of sweat glands and compared the reactions resulting from the current flow in places of different density of these glands. Tarchanoff also proved that it is possible to study changes in the electrical potential of the skin using two electrodes placed on its surface, without using an external power source (Neumann, Blanton, 1970).

Electrodermal activity is also present in the literature under the concept of galvanic skin response (GSR) or galvanic skin reflex (GSR). This term implies that the skin works exclusively as a galvanic cell, i.e. it generates an electric current through the chemical reaction resulting from the electrical contact of two different metals. However, the term is no longer used as it does not fully reflect the complexity of electrodermal skin

reactions (Boucsein, 2012). Using the concept of galvanic skin reflex may also indicate that the observed electrodermal phenomena are reflective and do not include psychologically induced reactions (Handler, Nelson, Krapohli, Honts, 2010). Moreover, the ambiguity of the concept of galvanic skin reaction results from the fact that this term was used not only to describe phase responses, but also the whole electrodermal activity, including, among others, tonic reactions (Boucsein, 2012).

Changes in the electrical properties of the skin result from the activity of eccrine sweat glands and the processes occurring in the outer layer of the skin (Jagielnicki, 2010). Due to the fact that sweat is an electrolyte solution, the more pores are filled with sweat, the more skin conductance increases (Figner, Murphy, 2011). Thermoregulation is the main function of most eccrine sweat glands. However, it is believed that glands on the palmar and plantar surface are more sensitive to psychological stimuli than to thermal stimuli. In spite of the fact that eccrine glands are thought to be involved in mental sweating, this kind of sweating is usually most apparent on the palm and foot surfaces due to the high density of sweat glands in these areas (Dawson et al., 2007). From the point of view of marketing research, the focus is on the measurement of the electrical activity of the skin associated with the psychologically induced activity of sweat glands. While considering the importance of skin conductance as an indicator of emotional stimulation, it is particularly interesting that parts of the brain such as the amygdala, hippocampus and prefrontal cortex, which are responsible for higher mental activity, are involved in the control of eccrine gland activity as well. It is worth noting that these are parts of the limbic system, which is particularly important in the regulation of affective processes. Additionally, it has been observed that reflex skin conductance responses caused by emotionally uncharacterized stimuli do not require the involvement of designated brain areas responsible for higher mental functions (Figner, Murphy, 2011; Naqvi, Bechara, 2006).

Measurement methods, tonic and phase activity

The research conducted by Féré and Tarchanoff allowed for the separation of two primary methods of measurement of electrodermal activity:

- exosomatic method;
- endosomatic method.

The object of measurement in the exosomatic method is skin conductance or skin resistance. The measurement of electrodermal activity is performed by applying an external current source (Dawson et al., 2007; Handler et al., 2010). In the case of constant voltage, the electrical activity of the skin is recorded in units of skin conductance (SC). On the other hand, skin resistance (SR) can be studied if the current is maintained at a constant level (Boucsein, 2012).

The endosomatic method, on the other hand, examines electrical potential of the skin without the use of an external source of current, i.e. solely based on the electrical activity of sweat glands. This measurement depends on determining the difference in

potentials between a selected measurement point and a reference point (i.e. between a place with higher and lower electrodermal activity) (Handler et al., 2010; Jagielnicki, 2010).

Concerning electrodermal activity, two basic elements can be distinguished: tonic and phase activity (Sosnowski, 1993). Tonic activity is an expression of changes occurring in the general level of autonomous stimulation (Bazarnik, 2016) and refers to the characteristics of the background signal (i.e. general level, slow increase or slow decrease in time) (Braithwaite et al., 2013). In the case of the tonic level, there are only slight changes over several dozen seconds or several minutes. Moreover, there are significant individual differences in this parameter, limiting the usefulness of tonic activity in marketing and other analyses (IMotions, 2017). From this point of view, much broader interpretative possibilities exist in the case of the second component of electrodermal activity – phase activity. This term refers to any rapid reactions in the skin conductance, usually caused by external or internal stimuli (Sosnowski, 1993). It should be noted, however, that some phase electrodermal reactions occur without stimuli and are referred to as non-specific or spontaneous electrodermal reactions (Boucsein, 2012). They can be observed in the body generally every 1–3 minutes. Unlike non-specific reactions, changes in skin conductance caused by specific stimuli occur within 1–5 seconds after their occurrence (IMotions, 2017).

The subject of measurement

Depending on the method of measurement and the component of electrodermal activity, it is possible to measure a number of parameters. The exosomatic method is used to measure the skin conductance, the unit of which is siemens, and the skin resistance, which is expressed in ohms. Within the tonic activity, the subject of measurement is, therefore, the skin conductance level (SCL) and skin resistance level (SRL). Phase activity parameters measured in this way include the skin conductance response (SCR) and skin resistance response (SRR). The endosomatic method is used to measure the skin potential, which is expressed in microvolts. In terms of tonic activity, the skin potential level (SPL) is measured and in the case of phase activity – the skin potential response (SPR) (Boucsein, 2012; Handler et al., 2010; Shaffer, Combatalade, Peperi, Meehan, 2016; Sosnowski, 1993).

The most popular way of measuring electrodermal activity is an exosomatic method. It may be divided into two types – with direct current (DC) and alternating current (AC) (which is rarely used). Measurement of EDA while using the direct current method may be performed using two techniques – direct voltage or direct current. The constant current method allows for the measuring of skin resistance – if a constant current of low intensity is applied to two electrodes placed on the skin, it is possible to measure changes in voltage, which are directly proportional to changes in resistance. In the case of constant voltage technology, skin conductance is measured (Boucsein, 2012; Handler et al., 2010). Direct current measurement using a DC voltage system is the most

widely used method for observing both phase and tonic electrical activity of the skin (Boucsein et al., 2012).

EDA measurement indicators

For the purposes of marketing research, it is worth looking at the indicators to interpret and compare during the EDA measurement. Due to the fact that the most frequently tested property is skin conductance, the most popular parameters describing this characteristic will be presented below. The basic parameter is the signal value, which gives information about the signal level at a given point. The recording of electrodermal activity provides information about the mean and standard deviation of the skin conductance response (SCR) – these measures include converting raw SCR into a standardised Z-result (with a normal distribution, a mean of 0 and a standard deviation of 1). The most commonly used measure of phase activity is amplitude, which is calculated as the difference between peak skin conductance response (SCR) and the low point before this peak (BIOPAC, 2017; Braithwaite et al., 2013; Naqvi, Bechara, 2006). In other words, it is a phase increase in skin conductance shortly after the onset of the stimulus (Dawson et al., 2007). With this technique, it is possible to measure the change in the skin conductance response to a stimulus over a specific time period (Naqvi, Bechara, 2006). The programs accompanying the measurement equipment provide the possibility to determine the maximum (max) and minimum (min) values, i.e. the highest or lowest amplitude of data samples between the endpoints of the selected area (BIOPAC, 2017). The interpretation of the results also may include the information on the frequency of the response, which refers to the number of single responses triggered by the stimulus presentation or to non-specific reactions in a given period of time not triggered by stimulus (NS-SCR) (Braithwaite et al., 2013). The basic parameters of electrodermal changes include latency, i.e. the period from the moment the stimulus is triggered to the moment the reaction occurs. The rise time is the interval between the beginning of the skin conductance response (SCR) and its peak. A commonly used measure is also the half recovery time, which means the time between the occurrence of the SCR peak and the point at which 50% of the SCR amplitude occurs, i.e. the time when the signal decreases by 50% (Dawson et al., 2007; Figner, Murphy, 2011). When a stimulus occurs several times during measurement, and the mean skin conductance response (SCR) can be calculated, it is also possible to determine the mean amplitude or magnitude of the skin conductance response. Magnitude is defined as the mean value calculated for all observed stimuli, including those with a zero measurement value (i.e. including cases where no response occurred), while amplitude refers to the mean value calculated only for those with a measurable, i.e. non-zero response (Dawson et al., 2007; Sosnowski, 1993). A less frequently used parameter is the delta, which indicates the difference between the amplitude values at the endpoints of a selected area. If the cycles are defined (this can be done using “Find cycle” software functions), it allows the observing of the difference between the values if the onset and skin conductance response are defined as an initial and final event. In this case, it is the equivalent of the amplitude value in the analysis panel of a specific event (BIOPAC, 2017; Braithwaite et al., 2013).

Principles of conducting research on electrodermal activity

Electrodermal activity measurement is carried out with the use of special electrodes, electrode gels and recording devices. Most researchers record EDA by placing electrodes on the surface of the fingers or hands. It is particularly recommended to place the electrodes at the middle phalanges of the index and middle finger. This is due to the fact that these are areas of high electrodermal activity where the electrodes can be easily attached and which, at the same time, are not susceptible to interference by motion. Another recommended location is the palm at the wrist and the middle of the foot (Boucsein, 2012; Handler et al., 2010). Electrodes made of metal are most often used to perform the test while those made of other materials (e.g. carbon electrodes) are used less often. Usually, the measurement is performed with silver electrodes or silver electrodes covered with silver chloride, i.e. electrodes made of metal in contact with the solution of its own ions. In a DC system, it is particularly important to use the same metal for both electrodes – otherwise, the potential difference generated by different metals will polarise the electrodes. It is recommended that the contact surface of the electrodes with the skin should be one cm² (Fowles et al., 1981). There should also be a conductive gel between the electrodes and the skin as it is important to use a substance that preserves the electrical properties of the system. Since current flows through the skin when measuring electrodermal activity and the conductive gel interacts with the tissue on which it is placed, it is recommended to use a product with a similar salinity level to the skin (Dawson et al., 2007; Fowles et al., 1981). EDA is measured basically using an electrode gel containing chloride salt, with sodium chloride (NaCl) being the most commonly used (Boucsein et al., 2012).

The proper use of psychophysiological methods – including measurement of electrodermal activity – requires the application of several fundamental principles. Improper test procedure carries the risk of excessive simplification and may lead to erroneous conclusions. When analysing the electrical activity of the skin in response to the stimulus exposure, it is important to remember about additional sources of information necessary for its interpretation. It is crucial to understand the context in which the stimulus is applied, to know the psychophysiological properties of the body and to identify other events that may influence the observed processes (Stewart, Furse, 1982). When designing a study of electrodermal activity, one should bear in mind the risk of artefacts i.e. changes in the recorded signal that does not originate from its source, but are the result of the recording procedure or physiological reactions not related to the electrical properties of the skin. One of the most frequent sources of interference in the measurement of electrodermal activity is motion – this applies not only to the areas where the electrodes are placed but also to muscle work in areas not adjacent to the apparatus, e.g. as a result of violent gestures (Boucsein, 2012; Boucsein et al., 2012). Further sources of artefacts include ambient noise, speech and physiological reactions such as coughing, sneezing or irregular and deep breathing (Boucsein et al., 2012). When measuring the electrodermal activity, care must be taken to ensure that the skin is properly prepared. Even washing hands with soap before the procedure may cause swelling of the skin and reduce its conductance (Lajante, Droulers, Dondaine, Amarantini, 2012). The result can be unreliable if the electrodes break away from the skin, if they are too

loosely attached or if there are problems with the cable connections. Avoid additional wrapping of the electrodes placed on the skin – this can put pressure on the skin and cause additional stimulus. Artefacts also occur when a test is performed in a magnetic field or outside a laboratory. Disturbances in measurement may also result from the placement of the test equipment on the dominant hand – the skin of the dominant hand is more often physically burdened, and its stratum corneum is usually thicker, which may affect the precision of measurement (Boucsein, 2012; Boucsein et al., 2012). When performing an electrodermal activity test, it should be remembered that the result may also depend on factors such as room temperature and humidity, daily rhythm and time of day, caffeine, medication or nicotine intake, as well as a previous exercise by the participant (Bell et al., 2018).

When making the analysis, it is worth considering that the source of variability of the obtained EDA results can also be demographic factors such as age, gender or culture (Boucsein et al., 2012). For example, when it comes to age-related differences, a significant negative relationship between age and skin conductance was observed in the studies of Barontini, Lazzari, Levin, Armando, Basso (1997). The level of skin conductance for older people is lower than for young adults. The study of Zelinski, Walsh, Thompson (1978) showed a lower phase activity in older people – comparison of mean skin conductance reactions (SCR) during the memory test resolution indicated that the level of this indicator was higher in young people.

Conducting electrodermal activity testing requires control of factors that may be potential sources of deviation in recording the results. When it comes to environmental conditions, among others, proper ambient temperature should be provided. It is recommended that the room where the test is performed should have a temperature of 22–24°C. However, this range is not appropriate for all conditions – it is recommended to adjust the temperature to the season of the year and the type of activity the participant performs during the study). Keeping the balance between too high (excessive sweating) and too cold (insufficient sweating) temperature is necessary. It is worth remembering that the EDA measurement is most often carried out in the laboratory, with participants most often being passive – higher temperatures are then recommended (Boucsein, 2012; Braithwaite et al., 2013).

Use of measuring electrodermal activity in marketing research

The specific electrical properties of the skin are the subject of analyses due to its dynamic changes and their relationship with psychological processes associated with sympathetic stimulation. Thus, measuring the electrical activity of the skin can provide information on the emotional aspects of decisions or assessments made (Figner, Murphy, 2011). EDA can be used as a measure of hidden emotional reactions, appearing without the participation of consciousness or going beyond cognitive control, in a situation of danger, anticipation, news or confrontation with a distinctive stimulus (Braithwaite et al., 2013). EDA finds application as an indicator of processes such as attention, habituation, arousal and cognitive effort, which is used in research in many disciplines

(Figner, Murphy, 2011). Studies on the electrical activity of the skin are used, among others in research in the field of psychopathology, personality disorders, conditioning or neuropsychology, as well as in marketing (Braithwaite et al., 2013).

What is particularly worth emphasising is that in recent years, there has been a noticeable increase in the number of publications on electrodermal activity (Figure 1). The number of searches for the phrase “electrodermal activity” in the EBSCO database indicates that the term appeared in 2020 publications from 1963 to 2018. Almost 35% of these sources (i.e. 705 publications) come from the last five years. An upward trend is observable when it comes to the number of search results for the concept of electrodermal activity in the last 25 years – this indicates that there are more and more publications about this method or research using it. EDA measurement is also a tool used in marketing research as EBSCO provides information on 18 such publications (the search criteria were the phrases “electrodermal activity” and “marketing”). It is worth noting that as many as 13 sources were created in the last five years. Considering that electrodermal activity has been present in literature for a long time under the term galvanic skin response, it is also worth looking at the number of searches for this phrase. This phrase appears in 10,741 publications, and the first sources come from 1945. Over 30% of searches (i.e. 3531) relate to works created in the last decade (Figure 2, note: the chart has a different scale than Figure 1) – this is more than half more than a decade earlier. The measurement of galvanic skin response has also been used in marketing research – since 1970 the term appears in 43 sources, of which over 80% have appeared in the last ten years (information applies to the simultaneous search for “galvanic skin response” and “marketing”).

Figure 1. The number of searches for the phrase *electrodermal activity* in the EBSCO database

Figure 2. The number of searches for the *phrase galvanic skin response* in the EBSCO database

The increase in the popularity of psychophysiological methods in marketing research was due to the limitations of the methods used to measure consumer reactions, i.e. self-report measures for assessing intentions, attitudes or emotions, and behavioural measures including actual buying behaviour, amount of money spent or time spent (Stewart, Furse, 1982; Wang, Minor, 2008; Wiles, Cornwell, 1991). In self-description techniques, there is a risk of providing socially acceptable answers (Wang, Minor, 2008). On the other hand, in the case of behavioural methods, it is difficult to determine the process that occurs between stimulus exposure and subsequent behaviour (Wiles, Cornwell, 1991). The premise for using psychophysiological techniques in marketing research is the ability to measure the objective and sensitive response of an individual to a stimulus that does not yield to conscious control. Thanks to this method, the subjects are not able to “mask” their real feelings (Stewart, Furse, 1982). Therefore, psychophysiological methods – including the measurement of electrodermal activity – have found their application in marketing research due to the need for a broader understanding of the mechanisms of the human mind. A particularly important area in this context measures the consumer response to external stimuli (Wang, Minor, 2008).

In marketing research, EDA was widely used as a measure of stimulation. A study by Groeppel-Klein and Baun (2001) investigated how different environmental settings in the stores affect consumer arousal and emotions when shopping. The study was carried out in fruit and vegetable stores, one of which was designed in accordance with the principles of environmental psychology, taking into account the special exposure of products. In the analysis of phase electrodermal activity, the sum of amplitudes was compared during a store visit, average amplitude per minute, skin conductance response frequency and duration of stay in a given store. Significant differences were observed in all parameters except average amplitude per minute. In the store with special

product display, customers stayed for a long time, and a higher level of arousal was observed.

In a study by Lajante et al. (2012) physiological arousal was measured as an indicator of emotional activation triggered by seven different television commercials (Coca-Cola, McDonald's, Spä, Bose, Pantoloc, Nikon, and Philadelphia). The authors of the study focused on how to most accurately examine the skin's conductance in the context of research on consumer behaviour. The following methods were distinguished: comparison of the overall level of skin conductance under various experimental conditions, comparison of mean changes of skin conductance before and after stimulus exposure and the sum of SCR amplitudes (which is considered one of the most popular indices). As an alternative, an integrated skin conductance response (ISCR) which reflects cumulative phase activity over a specific time period (e.g., from start to end of stimulus exposure) was found. The index correlates directly with the activation level of the sweat glands and allows the integration of both the spatial and temporal dimensions of SCR. For many authors, it is considered the most precise way to determine the phase activity associated with stimulus exposure.

In turn, the study by Gakhal and Senior (2008) concerned differences in the response of psychophysiological activity after the exposure of advertisements depicting celebrities or non-celebrities who were attractive or average-looking. It turned out that popularity – not attractiveness – is the factor that triggers a stronger electrodermal response. The study compared measurements based on the placement of electrodes on the right and left hands – but no significant differences in the levels of individual parameters were observed. The analysis was based on comparisons of the magnitude of EDA changes (expressed as a percentage) in relation to the highest amplitude estimated for each test condition.

In a study by Ohme, Reykowska, Wiener and Choromanska (2009), skin conductance was measured to determine the level of arousal resulting from the emission of two TV commercials of a skin care product that differed only in the presence of the gesture made by the model. The average skin conductance response between 21.5 and 24.5 seconds of the advertisement was recorded, i.e. when the gesture appeared in one version of the commercial. However, no significant difference in the level of stimulation was observed (only an outline of the trend). The study also used other neurophysiological methods (such as EEG), so it was possible to determine not only the level of arousal but also its direction. Other studies using the measurement of EDA to determine emotional arousal as a result of watching ads include Li, Walters, Packer, and Scott (2018) and Bolls, Muehling, and Yoon (2003), that examined the commercials in the tourism industry.

One of the first studies on the effectiveness of commercials using skin resistance measurement was conducted by Kohan (1968) who measured galvanic skin response and mean galvanic skin response in 10-second intervals. By comparing the GSR records with the analysis of experimental ads, it was observed that greater advertising interest is accompanied by higher peaks in skin resistance. The amplitudes and the exact moments of resistance increases varied between subjects, which may be due to the difference in skin resistance among individuals.

In a study conducted by Belch, Holgerson, Belch, and Koppman (1982), the physiological response of viewers to advertising was verified using sexually-oriented content. For this purpose, the galvanic skin response was examined and the results indicated that nudity and suggestibility of advertisements are associated with an increase in arousal among the subjects. A similar issue was verified by Kilbourne, Painton and Ridley (1985) in a study focusing on the effectiveness of sexual embedding in advertising. For this purpose, a galvanic skin response was measured – skin resistance was calculated based on the amplitudes of the reactions at intervals of 5 seconds. It was observed that a higher level of arousal appeared in response to advertisements containing sexual embeds.

Advertisements were also the subject of a study conducted by Aaker, Stayman and Hagerty (1986) in which the relationship between the sense of warmth induced by advertising and physiological stimulation was measured. To this end, the level of skin resistance was verified for warmth-sensitive ads with respect to humorous, irritating or informative ads. It turned out that warmth is associated with the occurrence of physiological arousal in recipients.

Electrodermal activity is used not only in studies regarding the physiological reactions in response to a specific stimulus but also in relation to consumer purchase decisions. Groeppel-Klein (2005) measured the electrodermal response (EDR) as the indicator of customer arousal at the point-of-sale (POS). The study assumed that the atmosphere of the store should attract customers and thus – induce phase electrodermal activity. Research has shown that arousal has proved to be a significant variable explaining consumers' shopping behaviour. It turned out that a store with a special design and display of goods caused a higher level of arousal compared to a store with a typical exposition – more purchases have been made in it as well. In addition, the level of arousal was higher for people who decided to buy. The conclusions were made on the basis of such EDA parameters as the sum of amplitudes and the frequency of responses (Groeppel-Klein, 2005). The use of EDA in relation to customers' choices also appeared in the study of Somervuori and Ravaja (2013), who analysed emotional processes and purchase decisions made in the context of changes in prices of the products of various brands. It was assumed that a higher level of electrodermal activity (and thus – increased arousal) while viewing the product image would allow concluding about its purchase. However, this hypothesis has not been confirmed as emotional arousal turned out not to have a significant impact on the purchase decision (Somervuori, Ravaja, 2013). Purchase decisions were also investigated in the Guerreiro, Rita and Trigueiros (2015) study, which aimed to explain how cognitive and emotional responses can influence the decision to purchase cause-related products of two categories – utilitarian and hedonistic. To this end, EDA was measured – the average skin conductance response and mean skin conductance response time was estimated. It turned out that a higher level of skin conductance or reduced time to reach the maximum level of arousal is associated with a greater likelihood of choosing a socially responsible product. Attention and emotional arousal are therefore autonomous reactions that affect the marketing effectiveness of this type of products (Guerreiro, Rita, Trigueiros, 2015).

The measurement of electrodermal activity in marketing research was also used to determine the physiological and verbal responses of consumers in relation to product packaging – these reactions were treated as indicators that allow predicting product selection. In the Vila-López and Küster-Boluda (2018) study, the electrical reactions generated by the skin were examined for six packaging designs of different colours and containing different information. During the analysis, EDA parameters such as the average EDA value, minimum and maximum values in specific time intervals and the peak (maximum) value were used to create the stimulation index. The study found that packaging of different colours (blue, red and black) and with different messages (simple or reinforced) lead to different physiological and cognitive responses that can ultimately influence the consumer's decision to try the product. Compared to self-report measures, it turned out that physiological responses are better indicators of anticipated consumer behaviour when choosing packaging (Vila-López and Küster-Boluda, 2018).

The electrodermal activity has also been used in examining consumer preferences for products. In a study by Walla, Brenner and Koller (2011), the attitude towards liked and disliked brand names was checked using skin conductance and other measures (including heart rate). For the purposes of analysing emotional aspects of brand attitudes, the average values of skin conductance were compared when reading their names. It turned out that the value of skin conductance associated with visual presentations of names of liked brands is significantly lower than that of disliked brands (Walla, Brenner, Koller, 2011). Different results were obtained in the Ohira and Hirao (2015) study which examined the skin conductance response (SCR) as a psychophysiological indicator to assess the affective aspects of consumer preferences for cosmetic products. The study procedure consisted of presenting images and descriptions of the combinations of two cosmetic products while recording skin conductance responses (SCRs), which were then evaluated by study participants. For the purpose of analysis, comparisons of mean and amplitudes of skin conductance reactions were made. The results of the analysis indicated that the average SCR amplitude elicited by preferred products was significantly higher than that elicited by non-preferred items. It is worth emphasising that one year later, the study was repeated with the same participants – their product preferences and corresponding SCR patterns remained stable. This means that the skin conductance response can be an indicator of consumer preferences in the long run (Ohira and Hirao, 2015).

Electrodermal activity was also used in the Hurley, Hutcherson, Tonkin, Dailey and Rice (2015) study on customer preferences for packaging. Electrodermal activity as a measure of emotional arousal was planned to be expressed in the form of an EDA arousal ratio constructed on the basis of minimum and maximum EDA value and the peak value (due to the low number of peak values, the mean normalised EDA value was used). The aim of the study was to check the relationship between the level of electrodermal activity and the data obtained from the eye-tracker. The study was conducted in a place reminiscent of a real retail environment – it proved difficult to engage the consumer in a natural way in experiencing emotional stimuli in such an environment. The results of the study conducted using eye-tracking technique turned out to be statistically insignificant. Also, EDA has not proved to be an important tool for measuring

arousal with regard to packaging in a purchasing environment (Hurley, Hutcherson, Tonkin, Dailey, Rice, 2015).

There have also been studies using the measurement of electrodermal activity in relation to the e-commerce market. Teubner, Adam and Riordan (2015) reviewed the affective processes and bidding behaviour of people participating in electronic auctions – due to the growing importance of computerized agents in this type of auctions and their impact on bidder decision-making. A laboratory experiment was carried out in which participants bid against other people and against computer opponents. The analysis used skin conductance response (SCR) measurement and compared the average SCR amplitude. It was observed that the level of intensity of immediate emotions of participants in response to events such as submitting a bid, winning or losing an auction, and the general level of arousal of bidders during the auction was mitigated in the case of a bid against computerized agents (Teubner, Adam, Riordan, 2015).

Attention measurement is another application of electrodermal activity in marketing research. For example, in the study of Bolls, Muehling and Yoon (2003), the impact of the advertising pacing on the voluntary and automatic attention of viewers was measured. Emotional stimulation measured by the skin conductance response was treated as one of the indicators of attention. It turned out that fast-paced ads caused significantly more skin conductance reactions than slow-paced ads. Thus, they can potentially increase the involuntary attention of TV viewers (Bolls, Muehling, Yoon, 2003).

To sum up, one should point to the spectrum of research using the measurement of electrodermal activity in marketing. Researchers used this tool to measure consumer emotional arousal, attention and affective responses associated with various stimuli (including warmth or anxiety) (Wang, Minor, 2008). Recording of the electrical activity of the skin was used to measure the effectiveness of advertisements, consumer preferences towards products or their purchase decisions.

Combining measurement of electrodermal activity with other methods

The measurement of electrodermal activity raises the potential to use it in marketing research along with other methods. In this regard, we can distinguish, among others eye-tracking, electroencephalography, facial electromyography, heart rate measurement, as well as self-description methods.

One of the first studies on the combined use of eye-tracking and measurement of electrodermal activity was conducted by Kahneman, Tursky, Shapiro and Crider (1969). Based on the measurement of heart rate, skin resistance and pupil size (using an eye-tracker), a similar pattern of autonomic responses was observed when solving tasks for all parameters – an increase in the collection and processing of information and their decrease in the reporting phase (Kahneman, Tursky, Shapiro, Crider, 1969). The issue of pupil size and electrodermal activity in marketing research appeared in the study of Rosa, Oliveira, Alghazzawi, Fardoun and Gamito (2017), in which a similar

pattern of pupil reaction and skin conductance in response to exposed stimuli was observed. For this research, the authors set out to discover whether there is a correlation between peak pupil diameter and skin conductance response (SCR) amplitude. The results indicated a relationship between these variables (Rosa, Oliveira, Alghazzawi, Fardoun and Gamito, 2017). In marketing research, eye-tracking is also used to measure eye fixation time at a specific point. This application of eye-tracking along with the measurement of electrodermal activity appeared, among others, in the study of Guerreiro, Rita and Trigueiros (2015) and Hurley, Hutcherson, Tonkin, Dailey and Rice (2015). The combined use of tracking eye movement and EDA can lead to a better perception of the role of pleasure, arousal and attention in predicting consumer behaviour (Guerreiro et al., 2015). The technique of tracking eye movements also allows assigning individual electrodermal reactions (including peak values) to specific objects on which the eyesight of the examined person is focused. Eye-tracking was used in such a way in the study of Colomer, Naranjo, Guixeres and Ausín (2014), where brain activity during commercial ad observation was analysed. Although skin conductance reactions were correlated with the level of brain activity, eye-tracking was used to depict the places where the eyes were directed by subjects during the moments where the peak values of these reactions occurred (Colomer, Naranjo, Guixeres, Ausín, 2014).

Neurophysiological methods used in marketing research along with electrodermal activity include measuring brain bioelectrical activity by means of electroencephalography (EEG). In marketing research, EEG is often applied to advertisements as it enables a precise description of the emotional response while viewing and identification of scenes generating the strongest emotional involvement, as well as describing the reaction to particular images, sounds, words or effects. By combining the EEG measurement with the analysis of the galvanic skin reaction it is possible to determine the nature of the energisation in response to a specific stimulation, i.e. to indicate whether the observed stimulation is positive (aspiration) or negative (avoidance) (Rafał Ohme, Pleszczyńska, Osiecki, Reykowska, Szczurko, 2010). The measurement of skin conductance in marketing research together with EEG was used in the Ohme, Reykowska, Wiener and Choromanska study (2009), where not only the level of stimulation while watching ads but also its direction was determined (Ohme et al., 2009). Other studies using both tools include Colomer, Naranjo, Guixeres and Ausín (2014).

The technique used in marketing research with the EDA is electromyography (EMG). This method records the electrical activity of the facial muscles as the movements of these muscles are part of the emotional response to exposure to the stimulus. They are spontaneously evoked and vary according to the type of stimulus and are consistent with the autonomous responses of the body (Dimberg, 1990). Also, in marketing studies, EMG is used as an indicator of emotional reactions (Wąsikowska, 2013). The measure was used together with the measurement of electrodermal activity in the following studies: Li, Walters, Packer and Scott (2018), Ohme, Reykowska, Wiener and Choromanska (2009), Somervuori and Ravaja (2013) and Wall, Brenner and Koller (2011).

Research has also been conducted using heart rate and EDA measurement. It is believed that the measurement of skin conductance more often reflects the level of arousal, while changes in heart rate include aspects related to the value of emotions

(Walla et al., 2011). In the Walla, Brenner and Koller study (2011) it was assumed that heart rate reflects the physiological response to popular and disliked brands. Bolls, Muehling and Yoon study (2003), on the other hand, treated heart rate as the measure of voluntary attention, while skin conductance was treated as an indicator of involuntary attention (Bolls et al., 2003).

The measurement of electrodermal activity as an expression of emotional arousal in response to external stimuli is often supplemented by self-descriptive measures. These measures include package evaluation scales (Vila-López, Küster-Boluda, 2018), advertising evaluation scales (Belsch, 1982; Kilbourne, Painton, Ridley, 1985;) and subjective measures of affective state (Rosa, Oliveira, Alghazzawi, Fardoun, Gamito, 2017). Verbal scales were also used in the Groeppel-Klein study (2005). Along with the measurement of electro-verbal activity, non-verbal scales are also used, such as the Manikin Self-Assessment Scale (SAM), which measures the pleasure and arousal during the decision-making process (Guerreiro, Rita, Trigueiros, 2015), while watching advertisement (Li, Walters, Packer, Scott, 2018) or during product package evaluation (Hurley, Hutcherson, Tonkin, Dailey, Rice, 2015). A non-verbal scale used in marketing research along with the registration of electrodermal activity is also the Warmth Monitor scale, which is a tool for measuring the sense of warmth induced by advertising (Aaker, Stayman, Hagerty, 1986).

In marketing research, psychophysiological methods are widely used and combined as emotional reactions, thoughts and actions of participants are measured by the electrodermal activity, the activity of the eyes, facial muscles, the heart or the brain. Supplementing these techniques with self-descriptive measures allows for a holistic examination of the analysed problem. The studies presented above may, therefore, be an inspiration for combining various techniques with the measurement of electrodermal activity.

Conclusions

The paper presents the method of measurement of electrodermal activity, its use and popularity in scientific literature. Basic indices and their interpretation are discussed, and examples of the possibilities of using the method in marketing research are presented. The article also discusses the possibilities and examples of combining EDA with other methods of measurement. Measurement of electrodermal activity is a tool for understanding the mechanisms underlying consumer behaviour. It allows us to learn about involuntary, unconscious reactions of consumers to products or advertisements. EDA – due to its connection with psychological processes – may be an indicator of arousal, attention or cognitive effort, as well as hidden emotional reactions that the respondents may want to mask. In marketing, EDA recordings are used to measure the effectiveness of advertising, preferences to packaging design and decision-making processes related to purchase behaviours.

References

1. Aaker D.A., Stayman D.M., Hagerty M.R. (1986). *Warmth in Advertising: Measurement, Impact, and Sequence Effects*. Journal of Consumer Research, 12(4), pp. 365–381. <https://doi.org/10.1086/208524>
2. Barontini M., Lázzari J.O., Levin G., Armando I., Basso S.J. (1997). *Age-related changes in sympathetic activity: biochemical measurements and target organ responses*. Archives of Gerontology and Geriatrics, 25(2), pp.175–186. [https://doi.org/10.1016/S0167-4943\(97\)00008-3](https://doi.org/10.1016/S0167-4943(97)00008-3)
3. Bazarnik A. (2016). *Aktywność elektrodermalna w metodzie biofeedback – zastosowanie kliniczne na przykładzie padaczki*. Nauki Ścisłe, 12(1), pp. 157–176. Pobrano z https://ruj.uj.edu.pl/xmlui/bitstream/handle/item/27792/bazarnik_aktywnosc_elektrodermalna_w_metodzie_biofeedback.pdf?sequence=1&isAllowed=y
4. Belch M.A., Holgerson B.E., Belch G.E., Koppman J. (1982). *Psychophysiological and Cognitive Responses to Sex in Advertising*. Advances in Consumer Research, 9(1), pp. 424–428. Pobrano z <http://search.ebscohost.com.00002bwy0b53.han3.ue.poznan.pl/login.aspx?direct=true&db=bsu&AN=6430757&lang=pl&site=ehost-live>
5. Bell L., Vogt J., Willemse C., Routledge T., Butler L.T., Sakaki M. (2018). *Beyond self-report: A review of physiological and neuroscientific methods to investigate consumer behavior*. Frontiers in Psychology, 9, pp. 1–16. <https://doi.org/10.3389/fpsyg.2018.01655>
6. BIOPAC (2017). *Acq Knowledge 5 Software Guide*. <https://www.biopac.com/wp-content/uploads/AcqKnowledge-5-Software-Guide.pdf>
7. Bolls P.D., Muehling D.D., Yoon K. (2003). *The effects of television commercial pacing on viewers' attention and memory*. Journal of Marketing Communications, 9(1), pp. 17–28. <https://doi.org/10.1080/1352726032000068032>
8. Boucsein W. (2012). *Electrodermal activity: Second edition*. Electrodermal Activity: Second Edition. Springer Science + Business Media, New York. <https://doi.org/10.1007/978-1-4614-1126-0>
9. Boucsein W., Fowles D.C., Grimnes S., Ben-Shakhar G., Roth W.T., Dawson M.E., Filion D.L. (2012). *Publication recommendations for electrodermal measurements*. Psychophysiology, 49(8), pp. 1017–1034. <https://doi.org/10.1111/j.1469-8986.2012.01384.x>
10. Braithwaite J., Watson D., Jones R., Rowe M. (2013). *A Guide for Analysing Electrodermal Activity (EDA), Skin Conductance Responses (SCRs) for Psychological Experiments*. <https://doi.org/10.1007/s10948-012-1909-2>
11. Colomer A., Naranjo V., Guixeres J., Ausín J.M. (2014). *Biosignal Analysis for Advertisement Evaluation*. [In:] XXIX Simposium Nacional de la Unión Científica Internacional de Radio. Walencja. https://www.researchgate.net/publication/270880230_Biosignal_Analysis_for_Advertisement_Evaluation
12. Dawson M.E., Schell A.M., Filion D.L. (2007). *The Electrodermal System*. [In:] Cacioppo J.T., Tassinary L.G., Berntson G. (Eds.) *Handbook of psychophysiology*. Third, pp. 159–181. Cambridge University Press, New York. <https://doi.org/10.1017/9781107415782>
13. Dimberg U. (1990). *Facial Electromyography and Emotional Reactions*. Psychophysiology, 27(5), pp. 481–494. <https://doi.org/10.1111/1469-8986.ep11032582>
14. Figner B., Murphy R.O. (2011). *Using skin conductance in judgment and decision making research*. [In:] Schulte-Mecklenbeck M., Kuehberger A., Ranyard R. (Eds.) *A handbook of process tracing methods for decision research: A critical review and user's guide*. Psychology Press, New York, pp. 163–184).

15. Fowles D.C., Christie M.J., Edleberg R., Grings W.W., Lykken D.T., Venables P.H. (1981). *Committee report: Publication recommendations for electrodermal measurements*. *Psychophysiology*, 18(3), pp. 232–239. <https://doi.org/https://doi.org/10.1111/j.1469-8986.2012.01384.x>
16. Gakhal B., Senior C. (2008). *Examining the influence of fame in the presence of beauty: an electrodermal "neuromarketing" study*. *Journal of Consumer Behaviour*, 7(4–5), pp. 331–339. <https://doi.org/10.1002/cb.255>
17. Groeppel-Klein, A. (2005). *Arousal and consumer in-store behavior*. *Brain Research Bulletin*, 67(55), pp. 428–437. <https://doi.org/10.1016/j.brainresbull.2005.06.012>
18. Groeppel-Klein A., Baun D. (2001). *The Role of Customers' Arousal for Retail Stores – Results from An Experimental Pilot Study Using Electrodermal Activity as Indicator*. *Advances in Consumer Research*, 28(1), pp. 412–419. Pobrano z <http://search.ebscohost.com.00002bwy0b8d.han3.ue.poznan.pl/login.aspx?direct=true&db=bsu&AN=6686451&lang=pl&site=ehost-live>
19. Guerreiro J., Rita P., Trigueiros D. (2015). *Attention, emotions and cause-related marketing effectiveness*. *European Journal of Marketing*, 49(11–12), pp. 1728–1750. <https://doi.org/10.1108/EJM-09-2014-0543>
20. Handler M., Nelson R., Krapohl D., Honts C.R. (2010). *An EDA Primer for Polygraph Examiners*. *Polygraph*, 39(2), pp. 68–108. https://www.researchgate.net/publication/265107219_An_EDA_Primer_for_Polygraph_Examiners
21. Hurley A., Hutcherson D., Tonkin C., Dailey S., Rice J.C. (2015). *Measuring Physiological Arousal Towards Packaging: Tracking Electrodermal Activity within the Consumer Shopping Environment*. *Journal of Applied Packaging Research*, 7(5), pp. 76–90.
22. IMotions (2017). *GSR Pocket Guide: Everything you need to know about Galvanic Skin Response to push your insights into emotional behavior*. pp. 1–36.
23. Jagielnicki R. (2010). *Biomedyczne urządzenie do monitorowania zmian rezystancji skóry. Pomiary Automatyka Kontrola*, 56(12), pp. 1568–1570. <http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-BSW4-0088-0049/c/Jagielnicki.pdf>
24. Kahneman D., Tursky B., Shapiro D., Crider A. (1969). *Pupillary, heart rate, and skin resistance changes during a mental task*. *Journal of Experimental Psychology*, 79(1), pp. 164–167. <https://doi.org/10.1037/h0026952>
25. Kilbourne W.E., Painton S., Ridley D. (1985). *The Effect of Sexual Embedding on Responses to Magazine Advertisements*. *Journal of Advertising*, 14(2), pp. 48–56. <https://doi.org/10.1080/00913367.1985.10672946>
26. Kohan X. (1968). *A Physiological Measure of Commercial Effectiveness*. *Journal of Advertising Research*, 8(4), pp. 46–49. <http://search.ebscohost.com.00002bwy0bc0.han3.ue.poznan.pl/login.aspx?direct=true&db=bsu&AN=5230256&lang=pl&site=ehost-live>
27. Lajante, M., Droulers, O., Dondaine, T. i Amarantini, D. (2012). *Opening the "black box" of electrodermal activity in consumer neuroscience research*. *Journal of Neuroscience, Psychology, and Economics*, 5(4), pp. 238–249. <https://doi.org/10.1037/a0030680>
28. Naqvi, N. H. i Bechara, A. (2006). *Skin Conductance: A Psychophysiological Approach to the Study of Decision Making*. [In:] Senior C., Russell T., Gazzaniga M.S. (Eds.) *Methods in mind*. Cambridge, pp. 103–122.
29. Neumann E., Blanton R. (1970). *The early history of electrodermal research*. *Psychophysiology*, 6(4), pp. 453–476. <https://doi.org/https://doi.org/10.1111/j.1469-8986.1970.tb01755.x>
30. Ohira H., Hirao N. (2015). *Analysis of skin conductance response during evaluation of preferences for cosmetic products*. *Frontiers in Psychology*, 6, pp. 1–5. <https://doi.org/10.3389/fpsyg.2015.00103>

31. Ohme R., Pleszczyńska I., Osiecki K., Reykowska D., Szczurko T. (2010). *Nowa generacja badań konsumenckich: eksperyment, czasy reakcji i fale mózgowe*. [In:] *Nowe trendy w reklamie. Między nauką a praktyką*. Wydawnictwo SWPS, Warszawa, pp. 76–96.
32. Ohme R., Reykowska D., Wiener D., Choromanska A. (2009). *Analysis of Neurophysiological Reactions to Advertising Stimuli by Means of EEG and Galvanic Skin Response Measures*. *Journal of Neuroscience, Psychology, and Economics*, 2(1), pp. 21–31. <https://doi.org/10.1037/a0015462>
33. Rosa P.J., Oliveira J., Alghazzawi D., Fardoun H., Gamito P. (2017). *Affective and physiological correlates of the perception of unimodal and bimodal emotional stimuli*. *Psicothema*, 29(3), pp. 364–369. <https://doi.org/10.7334/psicothema2016.272>
34. Shaffer F., Combatalade D., Peper E., Meehan Z.M. (2016). *A Guide to Cleaner Electrodermal Activity Measurements*. *Biofeedback*, 44(2), pp. 90–100. <https://doi.org/10.5298/1081-5937-44.2.01>
35. Somervuori O., Ravaja N. (2013). *Purchase Behavior and Psychophysiological Responses to Different Price Levels*. *Psychology and Marketing*, 30(6), pp. 479–489. <https://doi.org/10.1002/mar>
36. Sosnowski T. (1993). *Aktywność elektrodermalna*. [In:] Sosnowski T., Zimmer K. (Eds.) *Metody psychofizjologiczne w badaniach psychologicznych*. PWN, Warszawa, pp. 182–216.
37. Stewart D.W., Furse D.H. (1982). *Applying Psychophysiological Measures to Marketing and Advertising Research Problems*. *Current Issues, Research in Advertising*, 5(1), pp. 1–38. <https://doi.org/10.1080/01633392.1982.10505319>
38. Teubner T., Adam M., Riordan R. (2015). *The Impact of Computerized Agents on Immediate Emotions, Overall Arousal and Bidding Behavior in Electronic Auctions*. *Journal of the Association for Information Systems*, 16(10), pp. 838–879. <https://aisel.aisnet.org/jais/vol16/iss10/2>
39. Vila-López N., Küster-Boluda I. (2018). *Consumers' physiological and verbal responses towards product packages: Could these responses anticipate product choices?* *Physiology and Behavior*, 200, pp. 166–173. <https://doi.org/10.1016/j.physbeh.2018.03.003>
40. Walla P., Brenner G., Koller M. (2011). *Objective Measures of Emotion Related to Brand Attitude: A New Way to Quantify Emotion-Related Aspects Relevant to Marketing*. *PLoS One*, 6(11), pp. 1–7. <https://doi.org/10.1371/journal.pone.0026782>
41. Wang Y.J., Minor M.S. (2008). *Validity, Reliability, and Applicability of Psychophysiological Techniques in Marketing Research*. *Psychology, Marketing*, 25(2), pp. 197–222. <https://doi.org/10.1002/mar>
42. Wąsikowska B. (2013). *Współczesne technologie eksploracji danych w marketingu*. Zeszyty Naukowe SGGW w Warszawie. Polityki Europejskie, Finanse i Marketing, 9(58), pp. 588–599. http://www.wne.sggw.pl/czasopisma/pdf/PEFIM_2013_T9_nr58.pdf
43. Wiles J.A., Cornwell B.T. (1991). *A Review of Methods Utilized in Measuring Affect, Feelings, and Emotion in Advertising*. *Current Issues, Research in Advertising*, 13(1–2), pp. 241–275. <https://doi.org/10.1080/01633392.1991.10504968>
44. Zelinski E.M., Walsh D.A., Thompson L.W. (1978). *Orienting Task Effects on EDR and Free Recall in Three Age Groups*. *Journal of Gerontology*, 33(2), pp. 239–245. <https://pdfs.semanticscholar.org/a8c5/260d66b7f5e32120611e05b795130a0ed65b.pdf>