The aim of the research was to identify the pattern of psychophysiological response to emotional stimulation in adults with chronic stuttering.

The need to tell a lie functioned as emotional stimulation. Reaction to the stimulus was defined as the change of electrodermal activity (EDA), heart rate (HR), thoracic breathing (TB), diaphragmatic breathing (DB) and respiratory rate (RR) observed 10 seconds before and after the emotional stimulation. Reactions were recorded using Professional Computer Polygraph PIK-02 manufactured by Areopag-Center. The subject group included 68 persons with chronic stuttering (PWS) (24 women and 44 men) as well as 62 healthy non-stuttering persons (PWNS) (18 women and 44 men).

Adult patients with chronic stuttering were observed to increase the amplitude and reaction field as well as reduce the EDA latency. The researchers also noticed both increased HR and the range of its changes. Respiratory reactions included a lower amplitude of TB, higher increase and major changes within DB as well as minor changes in RR.

Adult patients with chronic stuttering display a unique pattern of psychophysiological response to emotional stimulation, which is different from the one found in the control group.

Key word: speech, emotions, anxiety, heart rate
INTRODUCTION

Psychophysiological reactions and ways of measuring them

Psychophysiological reactions may vary, both in qualitative and quantitative terms. They are also believed to play a specific functional role. Such various reactions tend to be referred to as models of reaction and are characterised by: a relative degree in the changes of particular psychophysiological variables, the direction of changes of psychophysiological activity (an increase or decrease), a special combination of several psychophysiological variables, the time values of the reaction or its components (latency, time to reach the maximum) (de Catanzaro, 2003; Ekman, Levenson, Ekman & Friesen, 1983; Panksepp & Watt, 2011).

Differences in reactions are conditioned by individual properties (individual specificity), features of the stimulus (situational specificity) as well as the relationship between the person and the situation (motivational specificity) (Ekman, 1992). It should also be noted that there may exist models of psychophysiological reactions understood as a way of reacting physiologically which is typical of e.g., a given type of disorder (Baevskiĭ et al., 2007). This leads to the conclusion that a person’s predisposition to develop disorders may be related to a specific model of psychophysiological reacting (Bichescu-Burian et al., 2017; Siegle et al., 2015).

The most frequently measured psychophysiological reactions include electrodermal activity (EDA), heart rate (HR) and respiratory reactions.

Electrodermal activity-EDA

Electrodermal activity (EDA) is an electric activity that occurs on the skin and is measured on the skin surface. EDA develops thanks to the activity of eccrine glands, which triggers electric changes in the epidermis by changing the way sweat is discharged. The glands, which are innervated with the sympathetic part of ANS, are able to react to emotional stimuli. As a result, EDA is one of the most popular methods of arousal measurement. EDA, which is interpreted as a measure of the total stimulation of the sympathetic part of the autonomic nervous system (Blain et al., 2010; Dietrich & Roaman, 2001; Mardaga & Lalovaux, 2006). EDA is also an adequate measure of occurrence, latency and intensity of emotional reactions (Tarvainen et al., 2001). When analysing EDA, the following time parameters are assessed: latency time, duration of curve increase and decrease, as well as amplitudes and magnitudes, i.e., the parameters of reaction intensity (Dietrich & Roaman, 2001; Weisz & Czigler, 2006).

Heart rate-HR

Although there are numerous parameters that describe cardiovascular activity, the frequency of the cardiac muscle contractions (pulse) is applied the most often. The autonomic nervous system, whose two parts work antagonistically, is one of the factors that control activity of the cardiovascular system. The sympathetic part stimulates heart activity, while the parasympathetic one performs the
inhibitive function (Saul et al., 1988). Stimulation of the parasympathetic system (transmitted by the vagus nerve, which remains in permanent tonic tension) leads to a decrease in excitability, conductibility and intensity of contractions. Fibres of the sympathetic nerves act antagonistically towards the vagus nerve and increase excitability, conductibility and intensity of contractions. Since they do not reach the same level of tonic tension as the vagus nerve, increased heart rate much more frequently results from the limited influence of the vagus nerve than it does from stimulation of the sympathetic nerves, with the exception of such stressful situations as physical effort, blood loss or emotional arousal. In the above mentioned cases, an increase in the heart rate results from the stimulation of the sympathetic nervous system (Porges, 2007).

Respiratory reactions

The process of respiration is performed approximately 15-16 times per minute, and increased excitement is accompanied by increased respiratory rate, tidal volume and minute ventilation (Boiten, Frijda & Wientjes, 1994; Boiten, 1998; Gomez & Danuser, 2004; Gomez, Stahel & Danuser, 2004; Van Diest et al., 2001). These findings confirm that the more excited the patients were, the faster and deeper their respiration was, irrespective of whether excitement was positive or negative (Gomez & Danuser, 2004; Gomez et al., 2005).

Psychophysiological reactions and speech

Research analyses highlight the link between emotional arousal and the process of speaking. On the one hand, an increased excitement level may disturb the process of speaking. On the other hand, even the very need to speak may cause the excitement level to grow. In one of the experiments, EDA was being measured while patients with a high level of social anxiety were performing different tasks. The EDA level proved to be the highest in tasks involving speaking. Furthermore, patients with the highest EDA increase values also displayed the highest level of stress (Lombard et al., 1989).

Kleinow & Smith (2006) researched the relationship between autonomous activation, speech and motor coordination in children and adults, in which assessed were HR, EDA and the changeability of lip movement during speech. The ability to control the motor aspect of speech decreased along with the growth of the activation level. In another study, in which subjects were discussing topics which tend to evoke negative emotions, the researchers observed an increase in the HR and EDA levels as well as a greater number of mistakes made in the utterances (Burbridge, Larsen & Barch, 2005).

There have also been attempts at proving the link between emotional activation and speaking by examining patients with a high level of anxiety. In most cases the results indicate that the higher the anxiety, the greater the psychophysiological changes observed while speaking (Croft et al., 2004). Whereas a declining anxiety level during speaking results in speakers becoming less excitable and less alert (Zampera, 1997). Moreover, the relationship between the level of
emotional arousal and motor activities, including the ones related to speaking, has been confirmed (Coombes et al., 2009; Marsh, Ambady & Kleck, 2005).

**Psychophysiological reactions in persons with stuttering (PWS)**

The influence of different degrees of excitement on the course of speaking in PWS was examined by assessing the activity of the cardiovascular system (Jones et al., 2014; Kraaimaat, Janssen & Brutten, 1988; Peters & Hulstijn, 1984; Weber & Smith, 1990) and EDA (Jones et al, 2014; Kraaimaat, Janssen & Brutten, 1988; Peters & Hulstijn, 1984; Weber & Smith, 1990).

Peters & Hulstijn (1984) measured the EDA and pulse of PWS and fluent speakers during and after the following tasks: mirror writing, an intelligence test, reading aloud and spontaneous speech. The psychophysiological reactions of PWS while completing individual tasks were not significantly higher than those of fluent speakers. While the level of excitement during spontaneous speech was similar in both groups, a considerable difference in heart rate, contrary to the researchers’ expectations, was identified. Heart rate recorded before speaking increased by 0.5 beats per minute in PWS, and by 5.2 beats per minute in the control group. Thus, the increase for PWS was lower than that for the control group by 4.7 beats per minute. The EDA rise in the same phase was similar for both groups. As the authors explain, the observed increase in heart rate may be associated with a higher level of excitement occurring before the process of beginning (anticipating) to speak.

Weber & Smith (1990) copied the methodology adopted by Peters & Hulstijn (1984) and concluded that while anticipating speaking, PWS displayed a drop in heart rate by 1.2%, while the hearts of fluent speakers beat faster by 1.3%. The overall difference between both groups reached 2.5%. In this phase of the research, both PWS and the control group displayed a similar growth of EDA, and slightly higher average values were observed among PWS. Phasic changes were 0.15 in PWS and 0.17 in the control group, while the tonic changes value was 1.04 and 0.70 respectively. When speaking, PWS displayed an increase in heart rate by 5.7%, while this value reached 10.4% in the control group. Greater skin conductibility was similar for both groups and equalled 0.26/0.24 for phasic change, and 1.51/1.24 for tonic change. Both studies pointed to an interesting fact that the psychophysiological changes observed while getting ready to read are different from the ones noticed while getting ready to speak or during spontaneous speech itself. Therefore, it seems that the individual tasks which are related to speaking trigger a different level of excitement. Getting ready to speak is particularly difficult for PWS. According to Alm (2004), the situation makes PWS react with apprehension, which causes autonomous coactivation. This type of autonomous reaction is characterized by freezing, in which a certain level of motor and vocal inhibition is observed. Peters & Hulstijn (1991) also pointed to the similarity of stuttering and freezing. They claimed that the contracting laryngeal muscle, which makes vocalization impossible, may also be a part of the reaction of freezing.
A specific reaction in terms of PWS heart rate was also proved in the studies that involved manipulation of stress severity. The heart rate was lower by 7.6 bpm at a low level of stress, by 12.9 bpm at a moderate level of stress and by 20.5 bpm when the stress level was high. An increase in stress level was linked to an increase in speech disfluency. The experiment confirmed one of the most common observations that the frequency and severity of speech disfluency increases when a patient experiences emotions (Caruso et al., 1994).

Attempts have also been made to investigate the link between stuttering and the degree of psychophysiological excitement by comparing their levels measured before and after speech fluency therapy. The parameters that were assessed were as follows: EDA, HR, the level of anxiety and speech fluency. It was concluded that speech fluency increased and the anxiety level decreased after speech fluency therapy. However, it was not accompanied by a change in the model of psychophysiological reaction (Kraaimaat, Janssen & Brutten, 1988).

A lack of any specific model of psychophysiological reaction in PWS was observed in the research by Heittmann, Asbjornsen & Helland (2004), who compared PWS with chaotic speakers and a control group in terms of pulse changeability and EDA, both at rest and while taking memory and attention tests. Although PWS obtained the highest results in EDA and pulse changeability in all the tests, these differences were not statistically significant.

The psychophysiological reactions of children were also examined (Arnold et al., 2011, Choi et al., 2016; Jones et al., 2014). The results indicate that during exposure to emotional stimuli, the model for such reactions is different in children with stuttering (CWS) and those who speak fluently.

To sum up, it can be assumed that although the results referring to a particular model of physiological reaction in PWS are not always unanimous, some typical features can be identified. A typical model of pulse changeability was observed in most experiments. When PWS were speaking or getting ready to speak, their heart beat would become faster, though to a smaller degree than in fluent speakers. Furthermore, the majority of the results prove that there are no differences in PWS EDA in response to different stimuli when compared to other groups.

**RESEARCH METHODOLOGY**

**Aim of the research**

The aim of the research was to identify the pattern of psychophysiological response to emotional stimulation observed in adults with chronic stuttering.

The influence of emotional variables in PWS was assessed by measuring PWS physiological reactions primarily in situations where patients had to speak compared to those that did not involve speaking. It had been assumed that the tests that involved the need for speaking would cause greater excitement. As a result, it would be possible to draw the conclusion that emotional stimulation caused by the necessity to speak would have a negative impact on the course of speaking.
The research paradigm was different for this study. The need to speak was minimized in the attempt to determine the pattern of the PWS psychophysiological response to emotional stimulation (the respondents were expected to reply only “no”).

If one attempts to test the pattern of psychophysiological response, it is advisable to avoid situations which involve speaking, as PWS most often find these difficult. We believe that one should rather create a situation which excites most people to a similar degree and is not linked to the existing disorder. Only then can one compare the pattern of psychophysiological response as displayed by PWS and fluent speakers. Otherwise, comparing fluent speakers and PWS in a speaking context means that we compare two realities which are inherently different by definition.

Prior to the research, the researchers had obtained permission from the Bioethics Committee and each of the participants had signed a written informed consent to participate.

### Participants

The subjects were volunteers and included 68 PWS – 24 women (35.29%) and 44 men (64.71%). The control group consisted of 62 people (29.04% were women and 70.96% were men) who were healthy and fluent (PWNS), and who were recruited on the basis of their age and sex. The average age was 27.2 years old for the subjects and 25.9 years old for the control group. A total of 77.94% of PWS and 61.39% of PWNS were city dwellers. People with secondary education constituted the majority in both groups (54.41%/95.16% respectively). Having analysed the subject literature, it was concluded that psychophysiological responses do not correlate with speech disfluency, therefore, this parameter was not indicated in the study.

The primary criteria for the recruitment of PWS was the chronicity of their stuttering. The subjects had begun to stutter in early childhood (on average at the age of 4.32) and have been stuttering ever since. Having analysed the subject literature, it was concluded that psychophysiological variables do not correlate with speech disfluency (Davis, Shisca & Howell, 2007).

All the participants were informed about the aim of the study and gave their written informed consents for participation. Upon recruitment, participants were asked to refrain from coffee, alcohol and symptomatic medicines one day prior to the experiment. None of them suffered from any chronic diseases (neurological, cardiovascular, respiratory or psychiatric ones), nor did they take any regular medication or undergo psychological or psychiatric therapy. All of them had had enough sleep and none reported fatigue. They had never before been examined with a polygraph. Before the experiment began, all the participants had been asked to wash their hands.

### Equipment

A device called a polygraph was used in the experiment. This is a specialist device which is used to measure and record different types of physiological ac-
tivities, and can present the results in a digital form (Vrij, 2003). Currently, poly-
graphs are used both in scientific research and everyday practice (the police, secret service, psychology). The process of data obtaining and processing with a polygraph is typically managed by a computer (Baevskiĭ et al., 2007).

So far a polygraph has been used to measure the specific form of physiolog-
ical functions in the following diseases: functional disorders of the urinary system (Fukui et al., 1999), schizophrenia (Zampera, 1997), diabetes (Noffke & Roser, 2001), and dentophobia (Caprara et al., 2003).

In this study, the authors used a Professional Computer Polygraph PIK-02 manufactured by Areopag-Center, with Archont software installed. This model of polygraphs offers better precision in the transforming, amplifying and transmitting of signals to a computer.

Reactions measured and their parameters

EDA was measured using dry electrodes, which were applied directly to the skin and not through an electrolyte. The electrodes were placed on the middle and index finger of the right hand. The surface of the electrode was 1.2cm². The amplitude, latency time and reaction area were determined.

The pulse was measured with a HR sensor which analyses the blood flow in the peripheral blood vessels located close to the skin surface. The structure of the applied sensor is based on the phenomenon that human blood reflects and disperses rays of light of a specific frequency. By recording changes in the amount of blood which reaches a particular area of the body during individual heart beats, the peripheral blood flow rate referred to as pulse amplitude can be calculated. Since the frequency of such changes corresponds to the frequency of cardiac muscle contractions, a HR sensor is used as a simple method to measure pulse (Ciarkowska, 1993; Sosnowski, 2000). The sensor was installed on the right-hand thumb of each participant. Unfortunately, even the smallest thumb movement resulted in two artefacts (peaks) being recorded. However, as the experiment was used to determine heart rate (HR) only, this imperfect method is not a source of errors.

Changes in respiratory activity (diaphragmatic and thoracic) were recorded with breathing sensors, i.e., stretching-sensitive sensors which measure respira-
atory activity (they analyse changes in chest and stomach capacity during breathing) and changes in breath depth and pace. The sensors were located at the breastbone and diaphragm level (in the case of women, they were installed under the breasts). In the course of the examination, the researchers determined the thoracic and diaphragmatic breathing amplitude, breath frequency as well as comparing both groups in terms of thoracic (TR) and diaphragmatic (DR) breathing.

Experiment description

The need to tell lies was the emotional stimulation used in the experiment. The experiment had an implicit assumption that, on the psychological level, emo-
tional reactions are a natural response to telling lies (Ekman, 2003). Since in-depth analysis of interrelations between lying and emotional reactions remains beyond the scope of this article, anyone interested is encouraged to read the numerous works of P. Ekman, which are available in research databases.

However, analysing a lie was obviously not the aim of this experiment despite the fact that the stimulation procedure and the equipment used might indicate so. Lying was used as a stimulator of emotional reactions.

In order to avoid any distractions, each examination was conducted between 12 p.m. and 4 p.m., in a quiet room with the door closed, and with only the subject and the researcher present. In the room there was a desk and two chairs, a carpet on the floor and bare whitewalls. The room was darkened and the shades were down. The subjects were sitting on a chair with their back and arms supported, turned with their one side towards the researcher. Their right hand, on which the sensors were placed, was resting on the armrest of the chair.

Before having the sensors placed on their hands, the respondents drew one out of five envelopes and read what was written inside (a word, a number, and the name of a geometric figure). Each subject was instructed to disguise the information found in their envelope.

Then they had HR and EDA sensors installed on the fingers of their right hands, and diaphragmatic and thoracic breathing sensors installed around their bodies. The researchers ensured the sensors are installed in such a way that they neither moved nor caused any discomfort for the subjects. Then a detailed description of the course of the experiment was distributed among the patients, who were asked to assume a position which they found the most comfortable, and also not to move, sigh, sneeze or cough during the experiment. The subjects could change their position in between the consecutive stages of the examination. The preparation time understood as the time needed for the patient to calm down before the examination proper began, was approx. 20 minutes (Coles, 1983 after: Ciarkowska, 1993).

During the experiment, the stimulating procedures described by Bashore & Rapp (1993) (the name test) and Verschuere, Crombez, De Clercq & Koster (2005) (the envelope test) were applied.

In the course of the experiment, the researcher and the subject agreed on a list of four names (male or female), depending on the subject’s sex. The names were selected in such a way that they did not evoke any associations, either positive or negative, and included the subject's name as they are most often referred to by others. During the experiment the subject was asked: ‘Is your name …?’ with each of the names listed being used instead of the blank space (including the subject’s own name). Although a question with the real name would come as third among the other invented ones, the subject was expected to answer ‘no’ to all the questions. The sequence was repeated three times.

The stages to follow were connected with information hidden in the envelope which had been selected by the subjects who were asked questions such as: ‘Is there a number … / a word … / a figure … / the following set of elements … in
the envelope you have chosen?’ As previously, the expected answer to each question was ‘no’. Such a sequence was then repeated three times. Altogether, each subject did fifteen tests (1. names, 2. numbers, 3. words, 4. figures, and 5. numbers/words/figures, three times each). Each test included five elements: four to which the respondent was expected to answer honestly and one in which they had to lie. Therefore, during the experiment, each subject had to lie fifteen times.

The reaction recording period was set at 10s, which means that recording was switched on after the question was read out and then continued for 10s. This period is considered long enough for the reaction to occur, be recorded and return to the baseline (Benedek & Kaernbach, 2010). There was a one-minute break between the tests. The experiment lasted from 45 to 60 minutes.

After each experiment finished, the subject told the researcher which envelope they had selected. This information was noted down as extremely important for the process of calculation.

**Methods for data collection and processing**

Reaction to emotional stimulation was defined as a change of HR, breathing parameters and EDA recorded 10s after emotional stimulation (if the respondent was to tell lies) or just before emotional stimulation (if the respondent was telling the truth). When referring to these fragments of the research in the presentation and description of the results, the following phrases are used: ‘before emotional stimulation’ and ‘after emotional stimulation’. Only the data which did not include artefacts were analysed.

**Method for data transformation and reaction parameters identification**

The application of a polygraph makes it possible to obtain data depicted in the form of a chart and saved as a graphic file. The data saved are described accurately so that one knows which part of the study they refer to. However, such an approach to recording does not enable one to save reaction intensity value using the standard SI (the International System of Units). Therefore, any statistical analysis of such data requires software specially developed for that purpose which transforms the selected parameters of the reactions (excluding HR and RR) into predefined units. The figures were calibrated in terms of time scale only (a horizontal scale) as the programme would not provide any units in a vertical scale. For this reason the authors used their own units to determine height (H) and width (S), and one unit represented 100 pixels on the diagram. Similarly, the authors used their own units to determine area, and one unit represented 10000 pixels.

In order to mark peak height and width, the baseline was determined. Peak height (amplitude) was defined as the distance between the baseline and the top point on the chart, while width was understood as the distance between the intersection of the chart line and the baseline.

Latency is the time which passed from the moment of stimulus occurrence to the moment when the chart line is distorted to mark the beginning of a peak. The area value informs about the amplitude and duration (increase and decrease),
therefore it includes a complete description of the reaction analysed. HR and RR calculated by marking an average number of peaks in fifteen 10-second recordings before the stimulus and another fifteen ones after the stimulus. This was used to calculate the average number of heartbeats and breaths per minute.

Statistical analyses were performed using Microsoft Excel 2010. Due to the significant amount of data provided for each subject and parameter, the researchers calculated the average value from the fifteen tests performed. For example: an average EDA amplitude before emotional stimulation and after emotional stimulation was calculated on the basis of fifteen tests performed for a single person. Then the averages and standard deviations for each parameter of reaction were calculated for the subject groups. After the shape of distribution of the data analysed was determined, the researchers selected the $t$-Student test and used its procedure to calculate the significance of the differences between the values of a given parameter before and after emotional stimulation, both within the groups and between them. For example: calculated was the significance of the EDA amplitude differences before and after emotional stimulation both among the PWS and between the PWS and the control group.

Also, calculations provided an average level of change understood as a quotient of value difference before and after stimulus compared to the value before stimulus. The value was referred to as the relative difference. When multiplied by 100, the relative difference represents the percentage of the change of the parameter analysed after emotional stimulation.

\[
\text{Value before emotional stimulation} - \text{value after emotional stimulation} \times 100
\]

\[
\text{Value before emotional stimulation}
\]

The results of two-sample tests were supplemented with $d$ Cohen effect size values. The following formula was used in the case of independent data:

\[
d = \frac{2t}{\sqrt{df}}
\]
where:
\( t \) - Student test value,
\( df \) – degrees of freedom.
For \( t \) Student test for dependent samples, \( d \) Cohen values were calculated using the following formula:

\[
d = \frac{M_D}{S_{DD}}
\]

where:
\( M_D \) – mean of the differences between pairs of measurements,
\( S_{DD} \) – standard deviation of the differences between pairs of measurements.
The level of statistical significance was set at \( p<0.05 \).

RESULTS

Results of the EDA reaction examination

The data analysis in Table 1 shows that while the EDA amplitude increased after emotional stimulation in both groups, the value of its increase is statistically significantly higher in PWS. The \( d \) Cohen effect size value obtained (0.55) indi-

<table>
<thead>
<tr>
<th></th>
<th>PWS</th>
<th>PWNS</th>
<th>( t(p) )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EDA-amplitude of reaction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before emotional stimulation</td>
<td>3.94</td>
<td>1.16</td>
<td>3.77</td>
<td>1.04</td>
</tr>
<tr>
<td>After emotional stimulation</td>
<td>4.11</td>
<td>0.49</td>
<td>3.88</td>
<td>0.56</td>
</tr>
<tr>
<td>( t(p) )</td>
<td>1.069(0.3)</td>
<td>0.740(0.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative difference</td>
<td>0.043</td>
<td>0.031</td>
<td>0.029</td>
<td>0.025</td>
</tr>
<tr>
<td>Change in %</td>
<td>4.3%</td>
<td>2.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EDA-latency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before emotional stimulation</td>
<td>1.00</td>
<td>0.12</td>
<td>1.04</td>
<td>0.09</td>
</tr>
<tr>
<td>After emotional stimulation</td>
<td>1.01</td>
<td>0.05</td>
<td>1.03</td>
<td>0.06</td>
</tr>
<tr>
<td>( t(p) )</td>
<td>0.75(0.4)</td>
<td>0.50(0.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative difference</td>
<td>0.01</td>
<td>0.010</td>
<td>0.009</td>
<td>0.004</td>
</tr>
<tr>
<td>Change in %</td>
<td>1.2%</td>
<td>0.90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EDA-reaction area</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Before emotional stimulation</td>
<td>2.11</td>
<td>0.24</td>
<td>2.24</td>
<td>0.19</td>
</tr>
<tr>
<td>After emotional stimulation</td>
<td>2.23</td>
<td>0.11</td>
<td>2.28</td>
<td>0.14</td>
</tr>
<tr>
<td>( t(p) )</td>
<td>3.82(0.001)</td>
<td>1.32(0.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>1.5</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative difference</td>
<td>0.057</td>
<td>0.039</td>
<td>0.018</td>
<td>0.012</td>
</tr>
<tr>
<td>Change in %</td>
<td>5.7%</td>
<td>1.8%</td>
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</tbody>
</table>
cates a moderate level of interdependency between the data analysed. The average amplitude change was 4.3% for PWS and 2.9% for the PWNS. Also, the group of PWS displayed shorter EDA latency, which means that any reaction to stimulation occurs more quickly than in the PWNS. The average change in this respect reached 1.2% for PWS and fell by 0.9% in the control group, and the differences are statistically significant. The dependency level is moderate \( (d=0.66) \). The EDA reaction area is statistically significantly larger in the control group. The effect size value recorded \( (d=0.59) \) is moderate before stimulation and weak after stimulation \( (d=0.37) \). It is worth mentioning that PWS display considerably deeper changes (a more rapid growth - 5.9% as compared to 1.8%) in the reaction area after emotional stimulation. An increase in stimulation was statistically significantly higher in PWS, and the effect size for the data analysed was very strong \( (d=1.40) \).

Results of HR examination

Before stimulus HR is similar in both groups (Table 2), but after emotional stimulation it increased by 3.50 beats per minute, i.e., by 5.2%, and becomes statistically significantly higher than in the PWNS. The effect size value recorded points to weak relationship between the data analysed \( (d=0.40) \). On average HR increased by 2.28 beats per minute, i.e., by 3.4% in the PWNS. Differences after stimulus are statistically significant both within and between the groups. The effect size values recorded within both groups are very strong \( (d=1.42) \), while the relationship between belonging to the group and HR relative difference is moderate \( (d=0.53) \).

Results of respiratory reaction examination

The data presented in Table 3 indicate that the amplitude of TB before emotional stimulation is similar in both groups, and its after emotional stimulation values decrease in both groups, too. After stimulus an average TB amplitude is statistically significantly lower in PWS than in the control group, and the effect size value recorded is very strong \( (d=1.11) \). On average, the decrease reached 1.4% in PWS and 4.1% in the PWNS, with the difference being statistically significant. The effect size value obtained points to a very strong relationship be-

<table>
<thead>
<tr>
<th></th>
<th>PWS</th>
<th>PWNS</th>
<th>t(p)</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before emotional stimulation</td>
<td>67.46</td>
<td>6.28</td>
<td>67.16</td>
<td>5.85</td>
</tr>
<tr>
<td>After emotional stimulation</td>
<td>70.97</td>
<td>3.42</td>
<td>69.44</td>
<td>4.17</td>
</tr>
<tr>
<td>(t(p))</td>
<td>4.04(0.001)</td>
<td>2.50(0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td>1.4</td>
<td></td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Relative difference</td>
<td>0.052</td>
<td>0.035</td>
<td>0.034</td>
<td>0.014</td>
</tr>
<tr>
<td>Change in %</td>
<td>5.2%</td>
<td></td>
<td>3.4%</td>
<td></td>
</tr>
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</table>
between belonging to a group and the relative difference of DB amplitude \((d=2.81)\).

The amplitude of DB before and after emotional stimulation is statistically significantly higher in PWS. The size effect values are 0.81 and 1.69 respectively, which suggests a strong and very strong relationship between the data analysed. While the DB amplitude increases after emotional stimulation in both groups, the differences are statistically significant only for PWS. The average increase reached 3.8% for PWS and 1.6% for the PWNS, with the difference being statistically significant. The effect size value recorded is strong \((d=0.98)\).

The respiration rate before and after emotional stimulation is statistically significantly higher in PWS, and the size effect values indicate a moderate relationship between the data analysed \((d=0.66; d=0.74)\). However, it drops after a stimulus and the relative difference is similar for both groups.

The amplitudes of diaphragmatic and thoracic breathing before emotional stimulation are at a similar level in PWS (see: Table 4). The amplitude of TB after emotional stimulation decreases, while the amplitude of the DB one increases. The average change is higher in DB (an average increase by 3.8%) than in the TB one (an average decrease by 1.4%). The size effect value points to a very strong relationship between the data analysed \((d=1.42)\). The amplitude of TB before emotional stimulation is statistically significantly higher in the PWNS, and the size effect value

<table>
<thead>
<tr>
<th></th>
<th>PWS</th>
<th>PWNS</th>
<th>(t(p))</th>
<th>(d)</th>
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<tr>
<td><strong>Amplitude of TB</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Before emotional stimulation</td>
<td>5.14 (0.48)</td>
<td>5.09 (0.47)</td>
<td>0.52 (0.5)</td>
<td>-</td>
</tr>
<tr>
<td>After emotional stimulation</td>
<td>5.07 (0.26)</td>
<td>4.88 (0.25)</td>
<td>6.27 (0.001)</td>
<td>1.11</td>
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<tr>
<td>(t(p))</td>
<td>2.03 (0.05)</td>
<td>2.98 (0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td>1.43</td>
<td>-</td>
<td></td>
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<tr>
<td>Relative difference</td>
<td>0.014</td>
<td>0.002</td>
<td>0.041</td>
<td>0.029</td>
</tr>
<tr>
<td>Change in %</td>
<td>1.4%</td>
<td>4.1%</td>
<td></td>
<td></td>
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</tbody>
</table>

|                      |           |           |              |          |
| **Amplitude of DB**  |           |           |              |          |
| Before emotional stimulation | 5.18 (0.48) | 4.82 (0.42) | 4.56 (0.001) | 0.81     |
| After emotional stimulation | 5.38 (0.26) | 4.89 (0.30) | 9.53 (0.001) | 1.69     |
| \(t(p)\)             | 2.99 (0.01) | 1.08 (NS) |              |          |
| \(d\)                | -         | -         |              |          |
| Relative difference  | 0.038     | 0.002     | 0.014        | 0.013    |
| Change in %          | 3.8%      | 1.4%      |              |          |

|                      |           |           |              |          |
| **Respiration Rate** |           |           |              |          |
| Before emotional stimulation | 12.23 (0.32) | 12.05 (0.21) | 3.75 (0.001) | 0.66     |
| After emotional stimulation | 12.14 (0.31) | 11.95 (0.19) | 4.16 (0.001) | 0.74     |
| \(t(p)\)             | 0.93 (0.4) | 0.16 (0.5) |              |          |
| \(d\)                | -         | -         |              |          |
| Relative difference  | 0.007     | 0.004     | 0.008        | 0.001    |
| Change in %          | 0.7%      | 0.8%      |              |          |
is very strong (d=1.40). The amplitude level after emotional stimulation is similar in both types of breathing. In this group statistically significantly greater changes happen in the TB (an average decrease by 4.1%) than in the DB one (an average increase by 1.4%). The size effect value is very strong (d=1.35).

**DISCUSSION**

**EDA**

The experiment has proved that an attempt to conceal information (tell a lie) results in emotional arousal and the motivation to hide information, which enhances the physiological response observed as an EDA increase (Caldwell-Harris & Ayçiçeği-Dinn, 2009; Frazie, Strauss & Steinhauer, 2004; Naveteur, Buisine & Gruzelier, 2005; Verschuere et al., 2004). Limited EDA response during an attempt to hide information was noticed only in patients with an antisocial personality (Rittweger, Lambertz & Langhorst, 1997).

This trend was also found in the authors’ own research in which parameters of EDA activity such as amplitude and reaction area increased in a situation of lie telling, i.e., after an emotional stimulation. This means that an increase in stimulation in such a situation is observed both in PWS and in the PWNS. The level of EDA was statistically significantly higher in PWS. On average the amplitude in PWS increased by 4.3% and the reaction area in the same group grew by 5.9%. In the PWNS these were 2.5% and 1.8% respectively. In order to provide a complete description of EDA, it is worth mentioning that PWS reacted to emotional and non-emotional stimuli much more quickly (a shorter latency) than did members of the PWNS. In terms of the EDA reaction, PWS appear to be more reactive and unstable than the controls, and the same stimulus triggers
stronger autonomic stimulation in them. Members of the PWNS are more stable in terms of EDA changes.

The subject literature offers different explanations of EDA instability. Gilbert & Gilbert (1991) have proved that chaotic and ineffective coping with a given situation was connected with an EDA increase. Still, this was coping in an active way as the passive one is linked with an EDA decrease. Therefore, it appears that for some people in some cases passive coping may be a more effective strategy, despite being perceived as strengthening in adaptation. These revelations have been confirmed in studies by Crider (2008).

In view of the five-factor theory of personality, significant EDA changeability is connected with agreeability and lower conscientiousness (Costa, Thomas & Widiger, 1990), high EDA activity – with a relatively reserved and polite temperament, whereas EDA stability is associated with a clear and openly opposing approach. Crider (2008) identified two groups: those of stable EDA activity and those with the unstable one. Members of the labile group were quiet, reserved, good-natured, helpful and responsible, while those classified as stable were active, decisive, touchy and irresponsible. Quite the opposite relationship was observed between EDA activity and expressing emotional and contradictory impulses, which indicates that EDA activity may reflect individual differences in the ability to control emotions (Fowles, 2000). Firm emotional control of behaviours causes greater lability of physiological processes (Fowles, 2000; Richards & Gross, 2006).

It has also been concluded that when presented with new and emotional stimulation, patients in neuroticism display greater EDA lability and slow habituation, unlike the more stable patients who were less labile and displayed quick habituation (Stelmack and Geen, 1992). The EDA reaction was significantly stronger in patients with a strong need to avoid harm (this feature is close to neuroticism) than in those who did not express such a need Fusar-Poli, Landi & O’Connor, 2009). Schaaf, Miller, Seawall & O’Keefe (2003) have discovered that children whose behaviour indicated oversensitivity to sensory stimuli displayed stronger and considerably higher EDA as well as poorer adaptability skills.

To sum up, the results obtained enable the identification of the following EDA characteristics for adult patients with chronic stuttering exposed to emotional stimulation:

• Higher amplitude before and after emotional stimulation, amplitude increase after emotional stimulation by 4.3% on average.

• Smaller reaction area which increases after emotional stimulation (by 5.9% on average).

• Shorter latency.

All these parameters indicate higher reactivity and EDA instability. In chronic stuttering, emotional stimulation causes stronger stimulation of the sympathetic part of the nervous system, which indicates occurrence, duration and depth of emotional reactions.
Heart rate

The research carried out by Hira & Furumitsu (2009) demonstrated that heart rate was statistically significantly lower when telling the truth than in a situation of lying. Also, the research revealed a considerable decrease in heart rate while telling the truth during the course of the examination. This classic model of habituation was nonexistent in patients who were telling lies. The PWS group displayed an increase in heart rate by 3.5 beats per minute on average (5.2%) after an emotional stimulation (telling lies). Although the heart rate value before stimulus was similar in both groups, its increase is statistically significantly higher in PWS than in the PWNS (2.8 beats per minute, 3.4%).

The results of previous research point to the fact that in anticipating speaking, speaking and being in stressful situations, PWS experience activation of the sympathetic part of the autonomic nervous system and an increase in HR, which are significantly less intensive than in the PWNS (Caruso et al., 1994; Peters & Hulstijn, 1984; Weber & Smith, 1990; Baumgartner & 1983). Heitmann, Asbjornsen & Helland, (2004) have proved that for PWS the need to speak causes a higher increase in heart rate than in the PWNS. However, these differences were not statistically significant.

The direction of phasic changes of heart rate is linked to the type of reactions it refers to (orientative, defensive or surprise-oriented). When exposed to new and unknown stimuli, the cardiovascular system reacts orientatively, which is evident in a drop in the heart rate, whereas defensive or surprise-oriented reactions cause an increased heart rate (Strelau, 2001). The defensive reaction enables the organism to prepare to act or potentially escape from a harmful stimulus.

Furthermore, the heart rate slows down when one needs to observe or notice external changes (the environmental intake-rejection hypothesis). When external stimulation does not reach the individual, their heart beats faster (Lacey, 1967, after: Ciarkowska, 1993).

The reaction of the cardiovascular system also depends on the approach to an action requiring situation. A decrease in the heart rate is observed when an individual is unable to take any action in order to avoid the negative stimulus, in which case the parasympathetic system is activated. Active coping which requires prompt action leads to intensive stimulation of the sympathetic system, which results in a heart rate increase. Experiments by Orbist et al. are of considerable significance among psychological studies on the influence of the coping style on heart rate. These researchers concluded that the tonic increase in heart rate which is observed in stressful situations depends more on the way of coping with stress than on stress as such. Unavoidable stress which cannot be predicted causes smaller psychological and physiological changes than stress which can be overcome or controlled (Allen et al, 1987; Light & Orbist, 1983).

Moreover, as indicated by Obrist’s research considered also should be that the severity of changes in the cardiovascular system depends on individual differences in this respect, which are referred to as cardiovascular reactivity (Sosnowski, 2000). The heart rate displayed by most reactive people when actively
avoiding an electric shock reaches 120 u/min. For the least reactive it is only 76 u/min, and this value is comparable with the results of patients whose beta-adrenergic system has been blocked pharmacologically (Allen et al., 1987). Furthermore, there is evidence that changes in heart rate are different depending on the type of emotional stimulus. The less comfortable the stimulus becomes, the lower the heart rate is (Gomez et al., 2005, Palomba et al., 2000). Some researchers even claim that heart rate is sensitive to whether the emotion is positive or negative rather than to the intensity of the stimulation itself. The more negative the stimulus is, the slower the heart rate becomes (Frazie, Strauss & Steinhauer, 2004; Gomez, Stahel & Danser, 2004).

Although a decrease in heart rate is typically observed in reactions to negative emotional stimuli, the stimuli which trigger anxiety make the heart beat faster (Etzel et al., 2006; Pieper et al., 2010).

Kaiser, Beauvale & Bener (1996) have proved that phasic changes in heart rate are linked to differences in the particular dimensions of a person’s personality. When exposed to audio stimuli, patients with high scores on the scale of psychoticism have displayed smaller changes in heart rate than those with low scores. When an individual with high scores on the scale of neuroticism was expected to count stimuli, a higher increase in their heart rate was observed. On the other hand, Kaiser, Beauvale & Bener (1996) have demonstrated that, when exposed to faint audio stimuli, emotionally stable introverts are characterised by a higher decrease in heart rate. However, their heartbeat accelerated when an additional task of counting the stimuli was introduced. In another experiment, Richard & Eves (1991) observed a statistically significantly lower level of extraversion and a higher level of neuroticism in patients whose heartbeat increased considerably (at least by 4 beats per minute compared to the initial value) as compared to patients whose heartbeat would slow down. Women with a high level of neuroticism reacted to stress with an increase in their heart rate (Knepp & Friedman, 2008).

Myrtek (1984), employing research which involved 700 subjects in different experimental contexts, has stated that an analysis of the results does not enable one to draw any firm conclusions regarding the relationship between emotional lability and cardiovascular activity.

To sum up, it can be concluded that HR changes observed in adult patients with chronic stuttering and triggered by emotional stimulation are characterised by:

- A statistically significant increase after emotional stimulation.
- A statistically significantly higher level of changes as compared to the control group.

**Respiratory reactions**

In reaction to emotional stimulation, the amplitude of TB decreases in both groups, with the average decrease being 1.4% in PWS and 4.1% in the PWNS. In PWS the amplitude of DB before and after emotional stimulation is statistically
significantly higher. Although in both groups the amplitude increases after stimulation, the differences are statistically significant only in PWS. On average, the change was by 3.8% in PWS and by 1.4% in the PWNS. The respiration rate after emotional stimulation drops in both groups to a similar degree.

On the basis of previous research, it can be concluded that respiratory changes are controlled mainly by the intensity of stimulation. The more intensive the stimulation is, the higher the tidal volume and minute ventilation become (Boiten, 1998; Gomez, Stahel & Dausner, 2004; Gomez et al., 2005; Han et al., 2004; Ritz, Georgie & Dahme, 2000; Van Diest et al., 2001). This means that the more excited we are, the faster and deeper our breathing is (Frazie, Strauss & Steinhauer, 2004). According to Boiten, Frijda & Wientjes (1994) & Boiten (1998), breathing models represent the general dimensions of a person’s response to what the situation demands. If a stimulus is interpreted as a challenge, it leads to an increase in metabolic needs. Therefore, fast and deep breathing is connected with the motivation to act.

Nevertheless, negative stimuli cause a reduction in thoracic breathing and the process is shifted to the diaphragm, which was observed in the PWS examined. This tendency was observed in the examined PWS. Although the amplitude of thoracic and diaphragmatic breathing was similar before emotional stimulation, the amplitude of TB started to decrease while the amplitude of DB began to grow after an emotional stimulus. In this way, TB in PWS exposed to an emotional stimulation is reduced and shifted to the diaphragm. There is a hypothesis that this constitutes a form of defensive reaction and the shift as such may have a reassuring effect (Applegate et al., 1983). Whereas, according to Von Leupold, Vovk, Bradley, Keil, Lang & Davenport (2010) the organism becomes prepared for the change of focus to external stimuli. While they were researching the influence of positive, negative and neutral images on the activity of the respiratory system in healthy people, they noticed a reduced tidal volume during exposure to both positive and negative stimuli. Such an effect was not observed in the case of neutral stimuli.

At the same time, the respiration rate in PWS decreases (i.e., they breathe more slowly) when exposed to emotional stimulation, though the differences are not statistically significant. In the research by Van Diest, Winters, Devriese, Vercaemst, Han, Van de Woestjine & Van den Bergh (2001) the respiration rate decreased during relaxation and when exposed to depressive images, whereas an increase was observed due to anxiety (Zampera, 1989). No differences in the respiration rate were found in people lying and those telling the truth during a polygraph examination (Hira & Furumitsu, 2009).

While the reduction of TB after emotional stimulation was significantly higher in the PWNS than in PWS, it was not followed by a considerable increase in the amplitude of DB. The respiration rate is statistically significantly lower in the control group both before and after an emotional stimulus. Having summarised our findings, the following changes in the process of breathing occur in adult patients with chronic stuttering exposed to emotional stimulation:
• A lower amplitude of TB and a higher increase in DB as compared to the PWNS.
• Greater changes in DB.
• Smaller changes in the respiration rate.

Our results can be interpreted in accordance with the microgenetic theory of symptom Kaczmarek et al, 2019).

CONCLUSION
1. A characteristic pattern of psychophysiological response to emotional stimulation has been observed in adult patients with chronic stuttering.
2. An increase in the amplitude and reaction area, along with a decrease in EDA latency.
3. Increased HR and deeper changes in it.
4. A lower drop of thoracic breathing amplitude, higher increase and deeper changes of diaphragmatic breathing as well as smaller changes in the respiration rate.

Limitations
The device used to measure the psychophysiological reaction may constitute a certain drawback for the research presented. We believe that an experiment based on similar methodological assumptions should be conducted using a different device for the recording of the psychophysiological reactions. The article does not answer the question as to the role of the changes observed, i.e., whether the characteristic of the psychophysiological reactions observed is the cause or the effect of the disorder.

Neither does the text analyse the relationship between the psychophysiological reactions and the level of anxiety, stress and self-assessment as well as the functioning of the central nervous system and motor skills, which the authors regard to be an interesting perspective for any future studies.

REFERENCES


Humeniuk et al. Psychophysiological response in patients with stuttering


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