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Electrodermal Activity in Polygraph Testing

Abstract. *Electrodermal Activity (EDA) is considered one of the most informative physiological responses to emotional stress, providing extensive data. This research is dedicated to investigating the measurement of EDA within the context of polygraph testing, utilizing the specialized LXSoftware. It includes a comprehensive analysis of EDA signal, with a particular emphasis on its correlation with various types of polygraph questions. Additionally, the study examines the characteristics of the EDA signal and factors that may potentially influence the measurements.*

Streszczenie. *Aktywność elektrodermalna (EDA) jest uważana za jedną z najbardziej informatywnych odpowiedzi fizjologicznych na stres emocjonalny, dostarczając obszernych danych. Niniejsze badanie poświęcone jest zbadaniu pomiaru EDA w kontekście testów poligraficznych, wykorzystując specjalistyczne oprogramowanie LXSoftware. Obejmuje ono kompleksową analizę oceny sygnału EDA, ze szczególnym uwzględnieniem jego korelacji z różnymi rodzajami pytań poligraficznych. Ponadto, badanie analizuje charakterystykę sygnału EDA oraz czynniki, które potencjalnie mogą wpływać na pomiary. (**Aktywność elektrodermalna w testach wariograficznych**)*

Keywords: Electrodermal Activity and Data, Skin Structure, Polygraph, LXSoftware, Scoring, Analysis.
Słowa kluczowe: Aktywność Elektrodermalna i Dane, Struktura Skóry, Poligraf, Oprogramowanie LX, Punkty, Analiza.

Introduction

Electrodermal activity (EDA) represents a comprehensive term encompassing various electrical phenomena associated with the the skin. It provides a non-intrusive and real-time indication of the sympathetic nervous system's activity, enabling the assessment of naturally occurring changes in the electrical properties of human skin.

In a historical context, EDA is sometimes inaccurately referred to as galvanic skin response or galvanic skin reflex (GSR), despite the fact that the galvanic process pertains to the generation of electric current as a result of a chemical reaction between distinct metals. The use of the term galvanic skin response would imply that the skin functions similarly to a galvanic cell. However, it is evident that in contemporary polygraphic systems employing exosomatic technology, no electric activity is induced by the attachment of electrodermal sensors to the examinee [1].

Among all the signals analysed during polygraph testing, the electrodermal response (EDR) is considered one of the most consequential and informative. There are numerous studies showing that the electrodermal element plays a significant role in enhancing the diagnostic precision within the framework of the comparison question test [2–4].

History

The investigation into alterations in the electrical properties of the skin finds its origins in the 1800s. In 1849, German doctor and physiologist DuBois-Reymond discovered the electrical activity of the skin. In 1878, a fundamental advancement occurred with the recognition of a correlation between sweat gland activity and the flow of electrical current within the skin. These seminal insights were the result of experiments conducted on a feline's paw pad by researchers Hermann and Luchsinger. Moreover, Hermann also discovered as the first that the palmar and finger regions of the hand exhibit more pronounced responses compared to other body areas. In 1879, the French researcher Vigouroux made the association between electrodermal activity and psychological stimuli based on observations made while working with emotionally distressed patients. In 1889, Russian physiologist Tarkhnishvili observed variations in skin electrical potentials that were unrelated to any external current source and correctly ascribed these variations to sweat gland activity. Around 1897, Alfred Stickler documented the first instances of utilizing electrodermal responses in the context of deception detection. They were presented in his contribution to Carl Jung's book, "Studies in Word Association," written in 1919.

The systematic scientific exploration of EDA started in the early 1900s as development in electronics facilitated more precise measurements with EDA component and improved the capacity to electronically store and analyse simultaneously recorded data. In the 1920s, William Moulton Marston found a connection between lying and increased blood pressure, constructing an early prototype of the polygraph. In 1921, John Augustus Larson augmented the device with a pneumograph enabling the simultaneous recording of multiple physiological responses, including blood pressure, pulse, and respiration. In 1939, Leonard Keeler expanded the polygraph with an electrodermal component, thereby creating a polygraph that concurrently recorded the three channels of respiratory, cardiograph, and electrodermal activity. These components are till now the mayor elements of contemporary modern polygraph systems. The final significant transformation occurred in the 1990s when polygraph data began to be processed on computers [5].

Structure of the Skin and Activity of Sweat Glands

The skin, along with other organs, constitutes the integumentary system, serving as a protective barrier against external influences. It is the largest organ in the human body, covering an area of nearly 2 square meters, safeguarding the body not only against viruses and bacteria but also aiding in maintaining optimal hydration levels and regulating body temperature through perspiration.

Comprising two primary functional layers, the outermost layer known as the epidermis and the deeper layer referred to as the dermis. It is organized into distinct sublayers. Beneath the dermis lies the subcutaneous layer, also known as the hypodermis or subcutaneous tissue, which connects the skin to underlying connective tissues. This subcutaneous tissue consists of a network of collagenous fibres containing adipocytes (fat cells), and its volume varies depending on the body's location.

The epidermis consists of five distinct layers, with each layer progressively becoming denser and more keratinized as it nears the surface. These layers are the stratum basale (also known as the stratum germinativum), stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum. Collectively, these layers represent different stages in the maturation of keratinocytes, constituting over 90% of the epidermis. Keratinocytes play a

central role in forming a protective barrier between the organism and the external environment. These cells originate in the deepest layer of the epidermis, move toward the skin's surface, undergo division, maturation, and ultimately desquamation, ensuring the continuous regeneration of the epidermis. In addition to keratinocytes, the epidermis also contains melanocytes, responsible for melanin pigment production, Langerhans cells that protect against pathogens entering the body through the skin, and Merkel cells, considered mechanoreceptors that are surrounded by nerve endings. Merkel cells are connected to the skin cells via specialized cell-to-cell junctions known as desmosomes. Cells in the stratum corneum join epidermal lipids, which form its protective barrier, and bind moisture within the skin. The epidermis is avascular, lacking blood vessels, with metabolic exchange occurring through diffusion from the vascularized dermis.

The dermis is the next layer, nourishing the epidermis, eliminating harmful substances from the body, and enabling perspiration. Comprised of connective tissues containing collagen and elastic fibres, enveloped in a gel-like substance rich in hyaluronic acid with a high water-binding capacity, the dermis is responsible for maintaining skin elasticity and volume. It is sometimes referred to as "true skin" due to its inclusion of lymphatic vessels that regulate body temperature, nourish the epidermis, and remove harmful substances. The dermis also contains hair follicles, nerve endings, and sebaceous and sweat glands, collectively producing fluids and forming the hydrolipidic film on the skin's surface, acting as a barrier against bacteria.

This comprehensive structure and function of the skin, with its various layers and components, ensure its pivotal role in the human body's overall well-being and protection against external environmental factors but also in enabling physiodetection through perspiration, which is triggered as a response to stress [6–9].

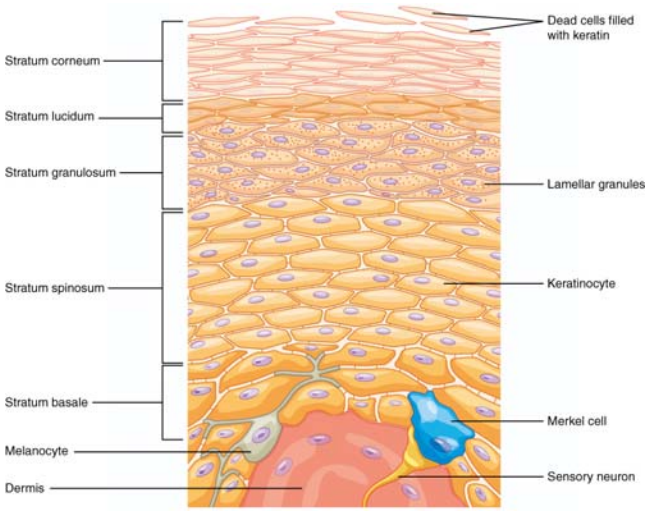

Fig. 1. Structure of the skin [6]

In moments of acute stress or heightened arousal, the activation of the sympathetic nervous system leads to the stimulation of eccrine sweat glands, subsequently influencing the electrical characteristics of the skin.

Sweat glands can be categorized into two types: apocrine and eccrine. Apocrine glands are relatively large and are located in the underarms, around the nipples, and in the external genitalia. Their activity commences during puberty and decreases with age. They are not particularly significant in psychophysiology. Eccrine glands, which are small sweat glands, are distributed across the entire body. They are most abundant on the palms and soles, absent only in the nail bed area and on the lips. Their count is estimated to range between 2-5 million. Sweat glands serve a thermoregulatory function, responsible for cooling the body's surface through perspiration and concurrently aiding in the elimination of waste substances. Importantly, the quantity of sweat secreted is not solely dependent on external conditions and body temperature but also on the individual's psychological state. Sweat contains ions that influence changes in skin conductance (SC) and skin potentials (SP) [6–9].

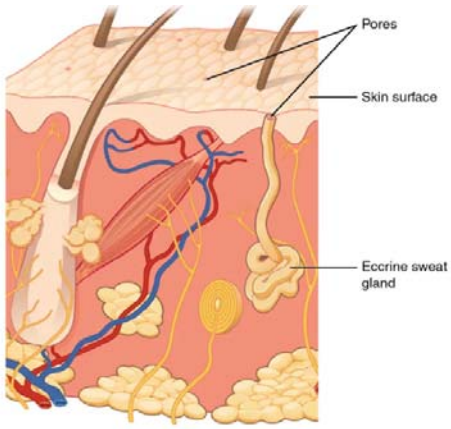

Fig. 2. Eccrine Sweat glands distribution in the Skin [10]

Examined Parameters of EDA Signal

EDA can be assessed employing two distinct methodologies: the endosomatic approach, which leverages the internal electric potential of the body without external current application, and the exosomatic method, which utilizes either alternating (AC) or, more frequently, direct current (DC). The advised upper limit for current density during psychophysiological measurement of EDA with human participants is 10 microamperes per square centimeter (10 μA/cm²) of skin.

In the domain of human stress research, DC is more frequently employed and is also utilized in polygraphy for assessing electrodermal activity. Systems employing constant current measure and record skin resistance (SR), expressed in ohms.

Constant voltage DC systems record EDA as skin conductance (SC), measured in microsiemens (μS). Hence, one siemens is equivalently the reciprocal of one ohm (Ω−1), it is also commonly denoted as the mho (℧). Skin conductance stands as the reciprocal of resistance, delineating a reciprocal relationship. Thus, when the magnitude of conductance is ascertained, the corresponding resistance can be mathematically inferred through the following correlation: 1 microsiemens of electrical conductance equates to 1 million ohms of resistance.

The endosomatic technique employs a differential amplifier to directly measure the electric activity originating from sweat glands. Subsequently, the acquired value is recognized as skin potential, measured in microvolts (μV).

Electrodermal Activity (EDA) delineates two distinct categories of physiological reactions to external stimuli, namely phasic and tonic responses. Phasic responses encompass swift and transient alterations occurring in the short term, often triggered by sudden stimuli. In contrast, tonic responses manifest as gradual and relatively long-lasting changes.

While phasic electrodermal responses mirror rapid fluctuations in the skin's electrical resistance over a span of

a few seconds, referred to as Skin Conductance Responses (SCRs), the broader tonic signal known as Skin Conductance Level (SCL) is measured on EDA over an extended period. The application of an electrical voltage across two skin electrodes generates an electrical current that is influenced by the skin's conductance level modulated by the secretion of sweat from the sweat glands. In the context of inducing acute stress through experimental paradigms, exposure to stressors is aligned with elevated SCL, followed by a reduction in SCL within a few minutes after the cessation of the stress-inducing stimulus [1, 5].

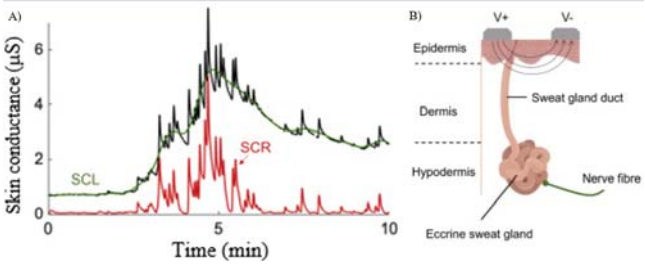

Fig. 3. A) Raw EDA signal (black line) encompasses both slowly changing tonic activity (green), representing the baseline skin conductance level, and phasic responses (individual peaks) vs. EDA signal in Detrended mode isolates the phasic rapid responses by minimizing the tonic component B) Representation of EDA measurement principle [11]

An electrodermal response that does not stem from a specific stimulus is labeled as spontaneous or nonspecific (Nonspecific Skin Conductance Response, NS-SCR, or Nonspecific Skin Resistance Response, NS-SRR). This encompasses spontaneous fluctuations in skin conductance, which are also observed during periods of rest [1, 5].

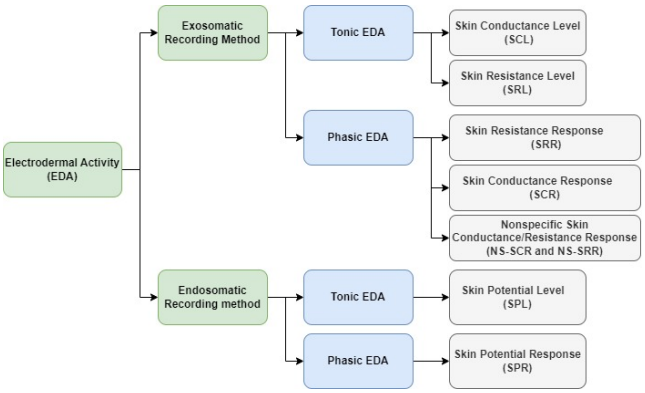

Fig. 4. Systematic hierarchical structure of electrodermal recording methods and types of measurement

The values of EDA are individual, although the normal range for skin conductance has been reported as 2uS to 20uS which is equivalent to 50kΩ to 500kΩ of skin resistance as they are inverse. It is important to highlight that an EDA value from a climber, for instance, will be markedly distinct from that of a young child. Consequently, the focus is exclusively directed toward variations, modifications, and the configuration of the waveform specific to an individual's physiological signal [1].

EDA Measurement in Polygraph Testing

EDA signals are captured using electrodes positioned on the palmar or plantar skin, depending on the measurement technique, types of electrodes, devices employed, or the research aim. However, similar to heart rate variability, EDA can be assessed for a few minutes or even over extended periods, utilizing wearable EDA devices that enable measurements spanning multiple days.

In the LX6 polygraph system, the two snap connectors are snap to the two finger plates, that are commonly situated on the index and ring fingers of the right hand during polygraph examinations. If necessary, these electrodes can be placed on the foot bottoms or in the armpits. Constructed from stainless steel, these finger plates are equipped with hook-and-loop fasteners. These electrodes exhibit reduced susceptibility to motion-induced artifacts and display lower resistance between the subject and electrode, facilitating more accurate signal acquisition [12–14].

Fig. 5. EDA electrodes placement [15]

Types of Testing Questions

During polygraph testing, the following three types of testing questions are most commonly used:

1) Irrelevant Questions

These are general questions used to establish a physiological baseline or to restore it. Typically, they focus on the subject's name, address, age, and other known information about the individual. They do not relate to the specific case under investigation and do not elicit emotional stress in the subject.

2) Relevant Questions

These questions are related to the specific case under investigation and the direct involvement in the crime. Since relevant questions are designed to compel a deceptive response, a strong physiological reaction to these questions is expected.

3) Comparison Questions

These questions are crafted to induce deception in the examinee in order to assess their credibility. An example of a comparison question is when the polygraph examiner states that the suspect, who is likely the perpetrator of the crime, will probably lie, followed by a question asking if the tested examinee has ever lied to someone close to them. If the subject is innocent, a stronger reaction is expected when lying to the relevant question compared to the comparison question. However, if the subject is guilty and lied to the relevant question, the reaction is likely to be higher than for the comparison question [13, 16]..

LXSoftware Set-up and Modes

EDA can operate in three modes: Manual, Automatic and Detrended. The manual mode displays the measured values without any adjustments. It uses the raw signal, which contains a higher amount of noise and is the most difficult to interpret. The noise is mainly caused by the natural evaporation of the sweat, which gradually decrease the measured values. The decrease in values itself has no informational value for the examiner. For the readability of the data in manual mode, it is either necessary to constantly centre the measured values (shift of the measured line to

the centre marked by an arrow), or to significantly reduce the resolution of the measured values, so that there is no loss of measured data by overflowing outside the graph (Fig. 6). This main disadvantage of manual mode is addressed by modes, which use software to filter out the mentioned noise [17].

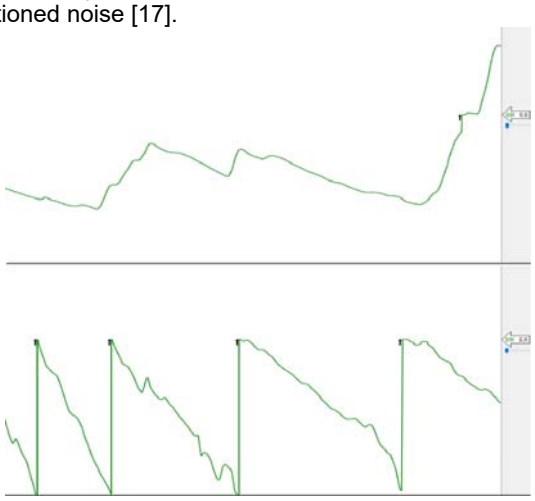

Fig. 6. Comparison of manual mode (top) with low resolution and manual mode with centring values (bottom) in two different measurements

Automatic mode works on the principle of filtering noise. It increases the readability of the measured values by reducing the decreasing trend, in a way that the measured values return to the centre value within 15 to 20 seconds. In automatic mode, less than 10% of the measured data is filtered. This can make it harder to detect some complex reactions or tonic reactions. However, the advantage of easier readability usually outweighs this disadvantage. The same is true for Detrended mode, which is based on a similar principle as automatic mode. It filters out descending (non-diagnostic) activity after the EDA data returns to the baseline but displays rising values in unfiltered form. The disadvantage of detrended EDA mode is that, like in Automatic mode, some tonic activity is hidden from the examiner in the resulting graph [17].

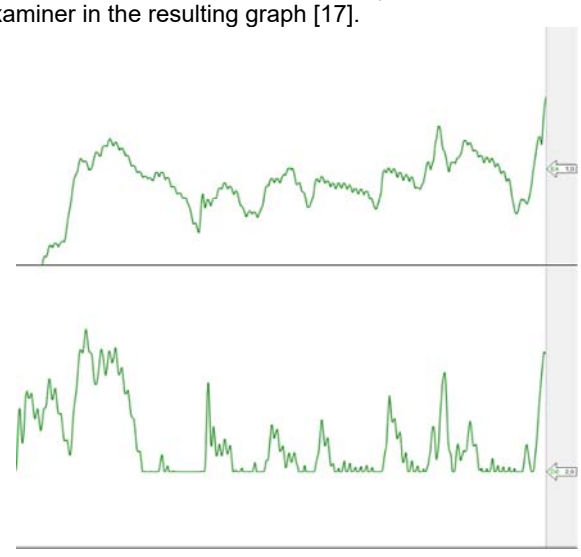

Fig.7. Comparison of Automatic mode (top) with Detrended mode (bottom) for the same measurement

In both filtered modes, emphasis is placed on preserving important data and hiding distracting noise that is irrelevant to the examiner.

Analysing EDA Data in Polygraph Examinations

In evaluating EDA, the following parameters are of primary importance: amplitude, latency, duration, and curve complexity. Latency signifies the time interval between the initial stimulus and the onset of the response, typically ranging from 0.5 to 5 seconds. Deviations from this interval, either shorter or longer, are uncommon and should not be considered for assessment. The following picture (Fig.8) depicts the skin conductance response as a physiological reaction to a stimulus with the mentioned temporal delay. Conductance rises to its maximum point and subsequently declines gradually to its baseline level [12,14].

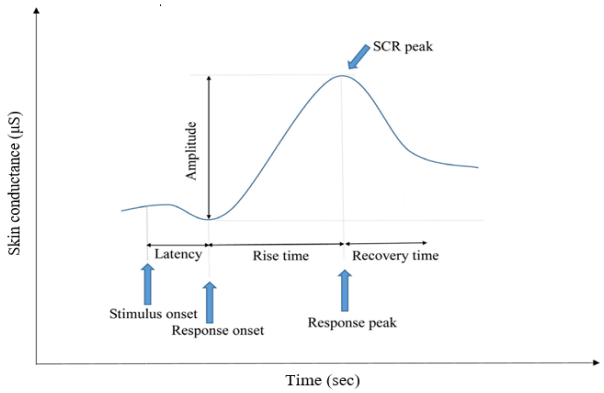

Fig. 8. EDA response pattern [18]

Evaluation is done by systematic scoring of changes between comparison and relevant questions. The two most prevalent scoring systems are the 3-position scoring and the 7-position scoring. Both systems assign values to each relevant question on every measured channel.
In the 3-position scoring system, a change in measured values is assigned a value of -1, 0, or +1. A negative value is attributed to larger reactions to a question compared to a comparison question, a positive value to smaller reactions, and 0 is designated for reactions without a discernible difference.

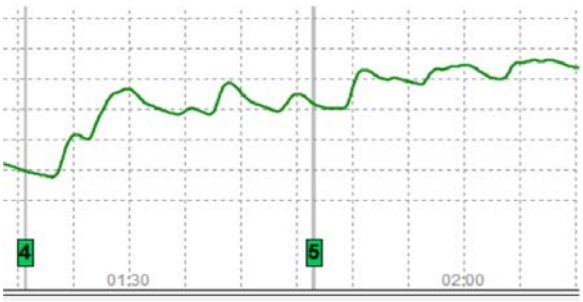

Fig.9. Noticable difference between questions 2 and 3

Fig.10. Significant difference

The 7–position scoring system extends from -3 to +3. The interpretation of 0 remains the same as in the 3-position scoring system, but positive and negative values are further differentiated. A higher absolute value signifies a more substantial change. An absolute value of 1 represents a noticeable difference (Fig. 9). An absolute value of 2 indicates a significant difference (Fig. 10). In this case there are still small similarities between reactions, but reaction on question 3 is significantly higher. An absolute value of 3 denotes a dramatic difference (Fig. 11), pattern has no simmilarities and amplitude of measured values are dramaticaly different. If we would have to assign score for Fig.11 with comparison question marked with 2 and relevant question marked with 3, assigned score would be 3. If the order of the questions were reversed (question 2 relevant and question 3 comparison) assigned score would be 3.

For sufficiently convincing detection of deception, both scoring systems typically require that the sum of scores from measured sensor channels are less than -3, and for an indication of no deception, the sum must be at least +3 [12, 19, 20].

Factors Impacting the EDA Responses

Various Factors impact negatively the recording of Electrodermal Responses (EDRs) in polygraph testing:

- Medications:

Sweat gland activity can be stimulated systemically using certain medications and substances.

- Demographics:

Age and gender disparities in EDA have garnered more attention compared to those associated with race and ethnicity. The aging process often leads to the development of skin wrinkles due to decreased tight binding between the epidermal and dermal layers. Consequently, there are reductions in sweat gland activity, ion concentration in sweat, and the number of active sweat glands. Furthermore, age-related changes in central nervous system structures such as the hypothalamus, which plays a role in EDA, could contribute to difficulties in generating EDRs. Summarizing relevant research, it appears that age-related physiological and psychological alterations may lead to diminished EDRs. Gender disparities have been identified in both sweat gland activity and overall sweat production. Women tend to exhibit a higher sweat gland density but produce less sweat. In a broad overview of gender-related studies, it can be concluded that women may have a heightened tonic EDA due to their greater sweat gland density. In contrast, men typically generate more pronounced EDRs under stimulating conditions. Additionally, skin colour has been shown to impact sweat gland density. Generally, individuals with darker skin tones tend to have fewer active sweat glands per unit area, resulting in elevated SCLs during periods of rest.

- Subject State:

The emotional state of an individual, including feelings such as stress, anxiety, excitement, and fear, can exert a not able influence on EDA responses. Intense emotional experiences typically result in increased skin conductance. Additionally, the individual's hydration status plays a role in affecting EDA responses. Dehydration or excessive sweating can lead to fluctuations in skin conductance levels. Another influential factor is the presence of skin conditions or injuries on the subject being tested, which can alter the electrical properties of the skin.

Experimental Conditions:

The factors like the type of stimuli presented and the study's experimental design, plays a significant role in recording EDA. Moreover, the precise placement of EDA sensors on the skin can have a substantial bearing on the precision of the measurements. It is imperative that the subject remains in a state of rest during polygraph testing. Although deceptive responses can also be elicited by subject's manipulation through realistic visualization or by intentionally taking deep breaths and making body movements during control questions. In response to relevant queries, subjects often strive to regain their composure.

Also, variations in ambient temperature have been shown to have an influence on EDRs, potentially leading to modifications in the skin's electrical properties. Typically, colder temperatures are associated with decreased phasic responses. This phenomenon is attributed to skin cooling, which has been linked to reduced EDR amplitudes, extended latencies, and prolonged rise times for phasic responses. Additionally, environmental conditions can impact skin permeability, indirectly affecting EDRs. For example, research by Fowles indicated that skin permeability to water doubled with a temperature increase of 7-8°C. To maintain optimal conditions, it is advisable to maintain a constant temperature of approximately 23°C, coupled with a consistent relative humidity level, aligning with the recommendations of Boucsein. This temperature range is chosen to prevent individuals from experiencing shivering, which may introduce motion artifacts, as well as excessive sweating, which could elevate the occurrence of non-specific EDRs [5].

Researchers and clinicians carefully consider these factors when conducting EDA studies and interpreting the data to ensure that their findings are both accurate and meaningful.

Fig.11. Dramatic difference

Discussion

Sympathetic nerve activity is primarily assessed by measuring electrical conductivity between two electrodes strategically positioned on the skin's surface, typically on the fingers or feet, where a concentration of nerves exists. Under stressful conditions, the skin's electrical conductivity increases significantly. This particular approach, referred to as exosomatic EDA, was the primary focus of our research. However, it's worth noting that EDA can also be passively measured, referred to as endosomatic, wherein potential activity is recorded.

The EDA signal encompasses two fundamental components: the tonic response, which is represented by the skin conductivity level (SCL), and the rapid phasic changes referred to as skin conductivity reactions (SCRs). These components serve as essential indicators of sympathetic activity.

EDA can be assessed in three distinct modes: Manual, Automatic, and Detrended. While the Manual mode provides raw data, the Automatic and Detrended modes present filtered data. These latter modes are designed to emphasize the preservation of critical information while

effectively concealing irrelevant noise, thereby enhancing the relevance of the data for examiners.

An essential facet of EDA measurement involves the evaluation and analysis of data. A comprehensive understanding of EDA signal variations and electrodermal parameters, including amplitude, latency, duration, and curve complexity, is essential.

In the context of a polygraph system, specific scoring systems have been meticulously developed to facilitate comparisons between changes observed in response to comparison and relevant questions. These systems are intricately described within the confines of this study. Furthermore, to ensure accurate evaluation, this research underscores the importance of mitigating factors that could potentially compromise experimental outcomes, such as medication usage, demographic variables, the emotional state of the subject, and the conditions under which experiments are conducted.

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