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Changes in Electrodermal Activity During Science Experiments: Preliminary Results of Case Studies with Six-Year-Old Children

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Abstract

This study aimed to investigate the electrodermal activity (EDA) of first graders during hands-on science activities. It was assumed that the effects of science experiments can cause changes in EDA. A special electrode placement was tested to measure EDA during the conduction of science experiments. Preliminary results of four case studies are presented in the article.

Keywords: Electrodermal activity, children, hands-on activities, science, measurement

1. Introduction

Psychophysical arousal becomes important even in the context of education when pupils have to achieve an objective. Research on which learning situation or context elicits how much arousal is essential to giving teachers an idea of the situations in which children are ready to learn and perform. The optimal arousal levels slightly differ from person to person: someone like a lower and others a higher level; however, people generally feel uncomfortable on a very low (i.e. sedated) or very high (i.e. overexcited) level of arousal. This would mean that at school, learning activities should not be too boring, nor too exhausting [1].

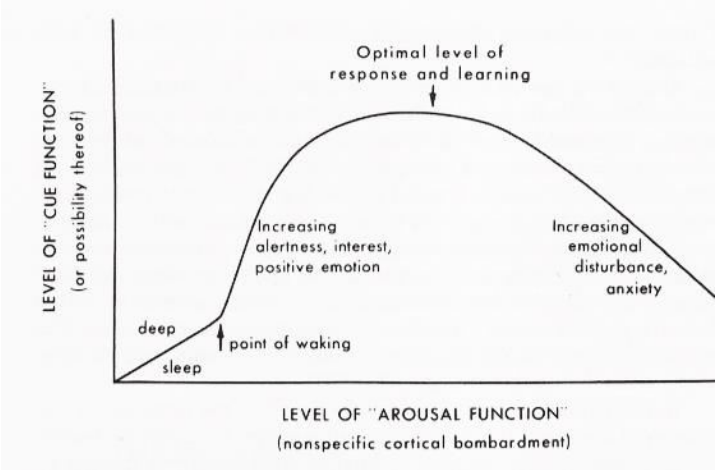

Figure 1. Interaction between arousal and performance [1, p. 250]

While studies show that primary school trainee teachers do not feel confident to teach physics content due to lack of knowledge [2], it is well known that children generally like to carry out science experiments. Some experiments create amazing effects and elicit fascination in children [3]. Beyond direct observations of children's reactions to science experiments' special effects, technical physiological measurements can offer an accurate insight into psychophysical activities during hands-on science activities [4].

An indicator to detect psychophysical activation is electrodermal activity (EDA), which reflects the autonomous nervous system's activity in response to sweat secretion. A low electrodermal activity indicates parasympathetic activity (inner calm), whereas a high one indicates sympathetic activity (inner tension). Compared to other parameters such as heart rate or temperature, electrodermal activity reacts within a remarkably short time [5]. Changes in EDA can be caused by increasing or decreasing cognitive or emotional load and physical activities. For example, novel and unexpected stimuli can evoke a phasic skin conductance response (short-term changes in EDA) and display an orientation reaction. Such reactions lead to increased attention to ensure optimal stimulus processing

in persons [6]. In this context, knowing which psychophysical changes can be observed in children during hands-on science activities could be revealing.
It is important to note that EDA varies from individual to individual and is influenced by age, gender [5] and temperament. Generally, EDA is higher when the child's temperament shows lower anxiety and lower inhibitory control. Therefore, due to individual differences, the same stimulus may not lead to the same changes in EDA [7].
Measurements of EDA, especially in young children and within the context of daily activities, are fraught with challenges: wearing the sensor may not be tolerated by children, children can be distracted by the sensor during the session, and children's physical activity can provoke many artefacts in data, among others. One of a few in situ EDA study with young children shows that sensors were better tolerated on the ankle than on the wrist, probably because the sensor was placed out of sight and children forgot the device [8].

2. Aims of the present study

This study aimed to explore whether changes in children's psychophysical arousal occur during hands-on science activities. For this aim, it was necessary to clarify if a special electrode position on the foot works with primary school children in a real learning situation in science education. Temperament was used as a control variable because this concept describes how individuals deal with their arousal.

3. Methods

3.1 Research design

Four single-case studies with six-year-old first-graders were conducted in a naturalistic laboratory study.

3.2 Procedure

The invited six-year-old participants came to the laboratory accompanied by a parent. The laboratory (with controlled room temperature) was child-friendly furnished (small chairs and table, nice pictures, soft-toys) and specifically prepared for video registration and EDA measurement. Happy children's music played in the background while children entered the room to create a pleasant atmosphere. One of the two researchers acted as a teacher and familiarized children with the room and the experimental materials.
Before beginning the science experiments, children were asked to put on a white lab coat and special motif slippers (e.g. Spiderman, Frozen). Then, after explaining what would happen next, an electrode was stuck to the sole of their foot (the skin was previously cleaned with rubbing alcohol), and the measuring device was hung around the ankle (see figure 2).

Figure 2. Adapted sensor and Shimmer device for EDA measurement

The second researcher was responsible for measurements controlling and synchronized video-registration from the background. The parent was placed at a distance from the child but in the child's visual field and was asked to stand down and complete a questionnaire.
The above-described procedure was part of a larger study that cannot be elaborated here. The focus of the present study is on the science experiments that started after a short sensor acclimation period.

Under the guidance of the teacher-researcher, the child – sitting at a table near to the teacher-researcher – carried out the following science experiments:

- Experiment 1: They filled vinegar into a bottle and baking soda into a balloon, put the balloon over the half of the bottle and observed that the balloon inflates when vinegar and baking soda come together.
- Experiment 2: They filled saltwater into a spoon, heated it over a tea-light flame and observed that a crust of salt formed on the spoon after some time.
- Experiment 3: They filled with a pipette red-coloured hot water into a small bottle, put the bottle into a high container of cold water and observed that the red water rose to the top.

Figure 3-4-5. Effects of the conducted science experiments

3.3 Behavioural observation

All sessions were video recorded. Child's behaviour was observed and evaluated by two independent, participating researchers.

3.4 EDA measurement

A Shimmer 3 GSR+ sensor was used to record electrodermal activity during the three science experiments' conduction. Since the Shimmer 3 GSR+ electrodes were designed for adult fingers, they did not suit children's hands nor the research situation's requirements. Therefore, finger-electrodes were substituted by self-adhesive, pre-gelled snap-electrodes (sintered Ag/AgCl) placed on the inner foot's plantar surface. This position allowed for proper signal recording [9; 5] and enabled children to freely move their hands. Special prepared Spiderman- (for boys) or Frozen-slippers (for girls) protected the electrodes with a hole on the respective place so that pressure on the electrodes was reduced, as recommended Boucsein and al. [5]. EDA data were analysed with the software Ledalab [10].

3.5 Questioning the parent

The "Integrative Child Temperament Inventory" in the German language version (IKT) was used to get information about children's temperament (behavioural inhibition, frustration, activity level, attention/persistence). Therefore, a parent had to rate 30 items [11].

4. Preliminary results

As the analyses have not yet been completed, only the first general results can be presented here.

4.1 Case study 1 (female)

- Behavioural observations: subject 1 allowed the electrode to be applied without hesitation, immediately established a good relationship with the investigator and had fun while experimenting. She was especially amazed by the balloon effect. Sometimes, she moved her legs and feet.
- EDA measurement: EDA data show phasic changes when the balloon was inflated (experiment 1); later, in experiment 3, phasic changes only occurred when the subject was handling the pipette. Artefacts were generally found in a clearly defined moment; hence, data are missing only for a part of the experiment, and other data were relatively artefact free.

- Temperament questionnaire: except for "frustration", where the subject reached below-average scores (PR = 20), all IKT scores were within standards.

4.2 Case study 2 (female)

- *Behavioural observations*: attaching the electrodes happened without any negative reactions from the subject. Subject 2 was very calm and did not move her legs or feet significantly. During the experiments she was very shy. She did not speak much with the investigator and generally showed little emotion, except for the balloon-effect.
- *EDA Measurement*: phasic activity could only be recognized during the balloon experiment while the balloon was blown. Only few artefacts were distributed over the entire duration of the experiment.
- *Temperament questionnaire:* subject 2 got scores within the standards apart from the scale "attention/persistence" (PR = 85).

4.3 Case study 3 (male)

- *Behavioural observations*: the placement of electrodes was accepted by subject 3. He was enthusiastic but also easily distracted during the experiments and had difficulties following the instructions. Towards the end of the experimental series, he stood up for a short time.
- *EDA measurement:* during hands-on activities phasic activity was found among the effects of the experiments but also in other situations not particularly relevant for the success of the experiment. Some artefacts were found, especially in the last experiment (vaporizing saltwater).
- *Temperament questionnaire:* subject 3 scored below the standard on the "attention/persistence" (PR = 5), "frustration" (PR = 10) and "behavioural inhibition" (PR = 15) scale. The "activity" score was above the test standards (PR = 80).

4.4 Case study 4 (male)

- *Behavioural observations*: initially, subject 4 was afraid of the electrodes and the slippers. After some minutes of playing a game and mother's encouragement, he accepted, that electrodes were placed on his foot. During experimenting, he was reserved and often reached with his hand towards the foot.
- *EDA measurement*: data showed a high number of artefacts over the whole course of the experiment; hence, phasic activity could not be extracted.
- *Temperament questionnaire*: Subject 4 evidenced the parameters "frustration" and "activity" within the standards. The IKT parameters "attention/persistence" (PR = 95) and "behavioural inhibition" (PR = 90) were over the standards, and "sensory sensitivity" (PR = 5) was below.

5. Conclusions

This exploratory study aimed to investigate whether measuring electrodermal activity in a learning situation close to reality at school is possible. Electrode positions were chosen by considering that subjects needed their hands to conduct hands-on science activities. All four subjects showed that participating in the learning activity – namely, the conduction of science experiments – was possible without limitations.

Since the study took place in a – for the child – foreign environment with foreign researchers, the mother's presence was unavoidable. In all four cases, electrodes could be placed with the help of the mothers, who significantly encouraged children to accept the electrodes on their feet. Only a male subject initially refused the electrodes but accepted them after becoming more familiar with the new environment.

Nonetheless, during the EDA data sampling, a lot of artefacts were collected due to subjects' temperament and the fact that children forgot to have a very sensible sensor on their feet. Each child was invited at least once not to move their feet. The subject with low "behavioural inhibition" and "attention/persistence" scores had especially severe problems to stay calm and showed many artefacts in EDA data, whereas the shyly female subject showed a few artefacts and few phasic activities. The male subject who felt uncomfortable, however, was behavioural quite restless and caused many artefacts.

Except for latter subject, all showed phasic electrodermal activity after perceiving the effect of the balloon experiment. This could indicate an orienting reaction in science activities that may be is essential for learning by engaging cognitive and behavioural resources toward a learning issue.

Apparently, of the three experiments carried out, the self-inflating balloon caused the greatest amazement and enthusiasm.
Overall, the four cases' analyses indicate that data sampling with an electrode placement on children's feet works under certain conditions, and electrodermal activity in hands-on science experiments can be captured. However, sessions must be limited in time not to overwhelm the child's task orientation, which would cause motoric deprivation and artefacts. Furthermore, subjects must be comfortable in the laboratory. Planning a habituation phase where the subjects become familiar with the investigator and the laboratory or guaranteeing the mother's or caregiver's presence is strongly recommended.

6. References

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