Estimating Orchestration Load in CSCL Situations Using EDA

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***Abstract*—This study investigates the extent to which Electrodermal Activity (EDA) sensor data can be triangulated with self-perception measures to estimate facets of teachers' orchestration load in the context of Computer-Supported Collaborative Learning (CSCL). It was expected to observe variances in the EDA signal as a result of stressful moments and incidents related to orchestration. Study findings indicated that EDA variations concurred with situations in which the teacher reported feeling stressed when orchestrating CSCL Pyramid scripts.**

***Index Terms*—Orchestration Load, Electrodermal Activity (EDA), Computer-Supported Collaborative Learning (CSCL), Teacher-Facing Dashboards**

I. INTRODUCTION

Managing learning situations while considering a number of practical constraints (e.g., time, space, curriculum) within everyday teaching and learning situations requires teachers' continuous effort. To refer to and emphasize the importance of relevant teacher tasks in educational settings, the community adopted the term *orchestration* [1]. The notion of orchestration load seeks to capture the workload teachers encounter when regulating multiple learning activities and processes [2]. It consists of both cognitive (monitoring students' learning progress, operating the supporting technology, deciding if modifications in the planned learning activities are needed, applying those modifications, etc.) and physical (moving across the class, distributing resources, etc.) components [3].

Orchestration load becomes an essential aspect to consider when designing tools and technologies for everyday classroom use. Especially in the context of Computer-Supported Collaborative Learning (CSCL), this notion is important to be considered given the diversity of tasks teachers encounter at different social levels, e.g., individual, group, and class levels. Teacher support tools that disregard orchestration load aspects in CSCL settings may introduce an additional burden for teachers instead of supporting activity regulation [2].

However, existing studies refer to orchestration load as a black box from which little is known about its contributing factors [4]. Moreover, there is a lack of instruments to measure this notion [2]. Understanding how orchestration load emerges in authentic learning situations and measuring this notion could inform design decisions for teacher supporting tools that could eventually support lowering teachers' burden. To this end, the present study investigates how novel tracking technologies, i.e., Electrodermal Activity (EDA), could be used to measure teachers' orchestration load in authentic CSCL situations. This paper explores to what extent EDA sensors can offer a layer of multimodal data informing about facets related to orchestration load. To do so, this research triangulates EDA data with self-perception measures (questionnaires) collected in the case of a teacher orchestrating Pyramid CSCL activities in six separate online sessions.

II. BACKGROUND

EDA is the umbrella term used for defining changes in the electrical properties of the skin [5]. The most studied aspect is the skin conductivity (SC, also called "skin conductance"), which can be quantified by applying an electrical potential between two points of skin contact and measuring the flow between them [5]. Physiologically, EDA is an electrical quantity linked to sweat secretion by the sweat glands [6]. Sweat glands are active, not only in thermoregulatory sweating but also during psychologically induced sweating (emotional sweating) as a result of different psychological states, such as excitement or stress, of a human performing a mental, cognitive task [6].

In psychology studies, EDA is considered as an index of affective degrees such as stress, strain, and excitement [7] [8]. Skin Conductivity Response (SCR) is a phenomenon that manifests as a sudden change in certain electrical properties of the skin, linked with sweat glands [9]. As observed by researchers, SCR is an indicator of cognitive efforts [10].

To assess orchestration load, it would be possible to use methods developed to measure cognitive load. The difference between the two is that the latter is usually measured in controlled lab environments while the former takes place in a class with students, which presents a diversity of variables that are virtually impossible to control. Introducing an activity to measure the cognitive load (e.g., a dual-task activity) of the subject is possible in a lab environment but quite challenging if a teacher has to do it while managing a class in real-time. Consequently, this requires the use of indirect measures of orchestration load, which track involuntarily physical reactions of the subject (e.g., temperature changes and pupillary dilation), and subjective measures (e.g., questionnaires) [2].

The increasing number of low-cost sensors available for different functionalities like measuring movement, and skin conductivity [11], provides new possibilities to study learning situations, both for teachers and students, such as in [12] [13] [14] [2]. However, we still lack reliable measures to estimate orchestration load [2] [4], which could be useful to inform design decisions for teacher support tools [15].

To approach the identified methodological gap to measure orchestration load, the following research question was defined: Can EDA be used to measure orchestration load in an online CSCL situation?

III. Methodology

A. Participants and environment

A female teacher from a Spanish university participated in the study. She had imparted classes for over 15 years and had experience authoring and orchestrating CSCL activities. Due to Covid-19, CSCL activities were conducted online using a tool called PyramidApp. PyramidApp implements CSCL scripts based on a particularisation of the Pyramid collaborative learning flow pattern [4]. The main criteria for selecting teachers to participate in this study was having prior knowledge and experience using PyramidApp.

In PyramidApp, collaboration is structured according to the Pyramid pattern as follows. First, students log into the activity. Then they provide an answer to a given task. At the end of the answer submission level, students are automatically grouped randomly. In small groups, students first evaluate the answers submitted by their peers individually using a star rating mechanism. Highly rated options are then available for discussion (using a built-in chat) at the small group level. Within the small groups, students can either agree to promote an existing answer to the next Pyramid level or can formulate a new answer (using a built-in collaborative text editor) based on ideas presented in existing options. At the end of the small group level, small groups are merged, creating larger groups, where students can further discuss and improve the existing answers to reach a consensus for a given task.

A teacher-facing dashboard built into PyramidApp aimed at facilitating orchestration. The dashboard presented real-time students' activity participation and controls that enable activity regulation (i.e., increasing time, pausing an activity, or ending an activity when required). More details about the dashboard are presented in [4].

The teacher was required to be present at a university office prepared for the data collection. The room was equipped with a desk, chair, and internet connection. The environment was neutral and had natural light coming from a windowed wall (Fig. 1, right). Occasional street noises could be heard.

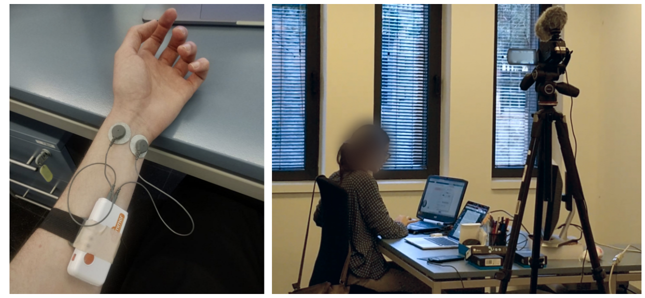

Fig. 1. Teacher at the office during a Pyramid activity. **Left:** The device was strapped to the subject's left forearm and the EDA sensors were placed on the inner side of the left wrist. Wrists are an unobtrusive location for the electrodes, which are proven to have intermediate skin conductance responsiveness [16]. **Right:** Camera and computer setup for data collection. A video camera registers the teacher's right side in a long shot while she orchestrates a CSCL activity using a computer.

B. Data collection and analysis

The teacher was tasked to orchestrate six online synchronous classes as she usually does with their students and to include a Pyramid activity using PyramidApp. Details of each Pyramid activity are shown in Table I. The dependent variable was the orchestration load of the teacher while imparting classes using PyramidApp. This variable was observed through a combination of data sources, namely, skin conductivity, post-activity questionnaires, video recordings, and dashboard screen recordings.

For each CSCL activity, after the recording equipment (described in this section) was set up by the researcher, the teacher was left alone in the room to impart class as they would normally do.

EDA was measured throughout the class using an electronic device with electrodes placed on the surface of the subject's skin (Fig. 1, left). This sensor provided information on skin conductivity and hand movement divided in the XYZ axis.

The teacher was video recorded in the environment throughout each class. The camera was pointed at the subject and the environment from a high angle, registering the subject in a long shot, so that her gestures were recorded (Fig. 1, right). PyramidApp's dashboard screen was recorded while the teacher orchestrated the Pyramid activity. After each activity, when all sensors were removed, the subject was asked to fill out a post-activity questionnaire. The questionnaire was designed to capture their perception of the activity and any stressful moments she might have experienced. The questionnaire is available in Zenodo [17].

Responses collected using the post-activity questionnaire were processed to identify stressful situations reported by the teacher. We watched the dashboard screen recordings and the video recordings of each activity to detect the precise moments in which the teacher mentioned that she felt stressed in the post-activity questionnaire. EDA information for each activity was plotted using line charts and visually inspected, which is a widely employed method for SC analysis [6] [18] [5]. Skin conductance was inspected to look for SCRs around the time of the stressful situations reported by the teacher.

IV. Results

Across all activities, the teacher reported eight stressful situations (See table II) through the post-activity questionnaire. The teacher's EDA was plotted for all Pyramid activities. EDA for activities no. 4 and 5 can be observed in Fig. 2. Figures with skin conductivity during all other activities are available in Zenodo due to limited space in the manuscript [19].

During activity no. 1, the teacher reported feeling stressed but "not highly" (see Table II, report 1.1) in spite of running out of time in her class. This event concurred with the highest SCR of the activity [19] which happened towards the end of the class she was imparting. During activity no. 2, the teacher reported sharing the wrong activity link with her students (see Table II, report 2.1). She realized this and read the activity she had shared while the students were participating in it. In the video recordings, the precise moment in which the teacher realized her error is unclear. Even though SCRs can be observed while the teacher is reading from her computer, we cannot assume they are directly or exclusively related to this situation. The teacher did not report feeling stressed during activity no. 3. During activity no. 4, the teacher reported feeling stressed because the activity she had planned to do was not published, and thus was not ready for the students to participate (See Table II, report 4.1). This report concurred with an SCR which was the highest peak of the activity (See Fig. 2, Plot A, highlight a). She also reported a malfunction with PyramidApp's dashboard where she tried to add time to the activity and the dashboard did not respond as expected (See Table II, report 4.2). This event concurred with an SCR, which in spite of being significantly smaller than the SCR related to the previous report in this activity, it is still a noticeable change in SC (See Fig. 2, Plot A, highlight b). During activity no. 5, the teacher first reported being surprised when the activity changed levels, as she was focused on reading the students' output (See Table II, report 5.1). The second report from the same activity was related to unexpected behavior of PyramidApp (See Table II, report 5.2). Likewise, the third report from activity no. 5 is related to the unexpected behavior of Collaborate, which is the distance learning software used by the teacher to impart classes (See Table II, report 5.3). Skin conductivity data from activity no. 5 shows SCRs for each of the stressful situations reported by the teacher (Fig. 2, Plot B, highlights c, d, and e). There was only one report in activity no. 6. Students told the teacher that they were having technical difficulties with PyramidApp (See Table II, report 6.1). A visible change in SC can be observed at the time where this problem took place [19].

V. Discussion

Upon analyzing the teacher reports, we can confirm that all of them are related to the teacher's real-time activity regulation or orchestration. Across all six Pyramid CSCL scripts, the most common activities related to teacher reports were instructing students, time-management, solving technical difficulties, and assessing learners' progress. These actions are widely recognized to be related to orchestration [20] [21] [13] [3]. Therefore, the findings of this study propose that data collected from EDA sensors, specifically the variations in EDA signal, can offer indicators of orchestration load in online CSCL situations.

TABLE I
Summary of all Pyramid activities

Activity No.	Duration (min)	No. of Students	No. of reports
1	9'	15	1
2	9'	16	1
3	9'	15	0
4	16'	14	2
5	18'	16	3
6	18'	15	1

TABLE II
Teacher self-reported stressful moments across activities.

Report No.	Report quote
1.1	I was **running out of time,** and needed to reduce time in the PyramidApp activity. However I'm used to this kind of situations, and was not highly stressed.
2.1	I noticed that the scenario for **the task that I shared with student was not the one I planned** (I have several ... and was confused with the one I picked) so **I had to read the scenario** while students where completing the Pyramid activity. In any case I know all scenarios very well and I could remember it quickly.
4.1	Prior to the Pyramid activity I noticed I **had not published the activity in PyramidApp.**
4.2	The time in a level was long, and I would have liked to to move to next level earlier. I increased the time in the first level twice, the first time addition work, but not the second time addition.
5.1	I did not notice when the initial submission level finished - I was not paying attention to time as I was concentrated in reading students' submissions
5.2	The first level finished before the expected time in the time line
5.3	Before debriefing, the virtual classroom software stopped working and **I needed to restart my browser** (this moment was more stressful than the others)
6.1	When students told me that after increasing time in a level of the activity **they could not continue editing** their improved answer

The teacher reports 1.1, 4.2, 5.2, and 6.1 (See Table II) took place while the teacher was instructing students on the activity or immediately after. These reports all have a concurring SCR. This observation is in line with a mixed-method case study by Prieto. et. al [21] in which they studied how orchestration unfolds and the cognitive load that the presence of technology imposes on the teacher. In their study, they observed that high cognitive load episodes were associated with explaining or instructing students.

Moreover, previous studies have shown that SCRs occur when a human changes their focus of attention [7]. Report 5.1 (See Table II) took place while the teacher was focused on the dashboard, reading students' answers and inspecting

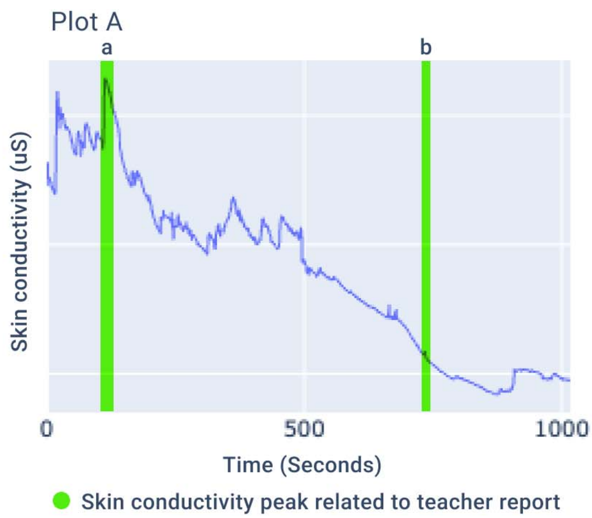

Fig. 2. Skin conductivity of the teacher during the Pyramid activities. Green highlights indicate SCR related to teacher reports (See Table II). Plot A (left) shows EDA during activity no. 4. Highlights a, and b are related to reports 4.1 and 4.2 respectively. Plot B (right) shows EDA in activity no. 5, highlights c, d, and e are related to reports 5.1, 5.2, and 5.3 respectively.

the activity of a particular group. Studies of cognitive load in teachers [20] [21] indicate that assessing student progress is associated with a high cognitive load. Emergent activities are defined as activities that are built based on what learners have produced in earlier stages of the learning scenario. In these activities, the teacher needs to read students' answers to assess their level of understanding of the topic being discussed. This is recognized as a highly demanding task [3] and the load generated when evaluating the epistemic information of the activity can also be referred to as "content load" [4] which was seen as an important load that teachers experience when orchestrating learning situations.

The teacher encountered issues with PyramidApp on multiple occasions across all activities. Reports 4.2, 5.3, and 6.1 seem to be related to issues with the software (See Table II). All of them concurred with an SCR. These findings align with the results of a study conducted by Al-Fudail & Mellar [13]. Problems with the usability of the technology including factors such as errors, compatibility, and reliability were identified as a possible cause of stress in teachers. In their study, teachers reported issues with their technological environment which were related to sudden increases in their EDA.

This study also adds to the evidence that supports the interest and opportunity of having objectives measures such as EDA to be used to monitor orchestration load [2]. Throughout all activities, teacher reports of stressful moments appear to be consistently related to SCRs. In activities no. 1, 4, and 5, the SCR associated with the teacher report is the highest of the activity (Fig. 2, [19]). This relationship might indicate that even though the teacher had SCRs throughout all activities, the highest EDA SCRs indicate orchestration situations where the teacher felt particularly stressed.

Yet, there were other multiple SCRs per activity besides those related to teacher reports. This could indicate that EDA detected skin conductivity peaks in situations where the teacher did not feel particularly stressed nor remembered while completing the post-activity questionnaire. Understanding if these peaks relate to orchestration actions or facets of the orchestration load (even if not perceived as stress by the teacher) requires future research.

This study analyzes data from one female teacher (six activities). It is known that there are gender differences in EDA measurements [6] [22], so gender should be taken into consideration and the results obtained do not generalize to male teachers. Since the teacher needed to fit the data collection into their classes, she was allowed to design the activities in a manner that would not be obtrusive to her course. Because of this, the duration of each activity varied, ranging from 9 to 18 minutes. This study collected data from a university teacher using a Pyramid activity with PyramidApp in an online learning situation. Because of this, the results obtained do not necessarily generalize to other educational levels, other collaboration scripts, and face-to-face CSCL situations.

VI. Conclusion

The study findings show that EDA was successful as an indicator of stressful moments related to orchestration actions (and the derived load) of a teacher using PyramidApp in a CSCL situation. We reached this conclusion after analyzing the teacher's actions related to self-reported stressful situations and observing that all of them were related to orchestration. Some SCRs aligned with teacher-reported stressful situations, but other SCRs cannot be explained exclusively using the teacher self-reports. This could imply that other situations increase the skin conductivity response, which are not perceived by the teacher as stressful moments but are observable through EDA sensors. We think EDA is promising for future research work, considering it provides a different perspective to observe OL. Through involuntary reactions such as EDA, researchers can look into OL without relying exclusively on what the teacher reports. This research is also relevant to system designers building orchestration technology (e.g., real-time adaptation of supports depending on teacher physiological data, etc.) More detailed observations of OL will inform the design of more efficient tooling for teachers.

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