NEW METHODS DEEPENING UNDERSTANDING OF STUDENTS' EXPERIENCES AND THEIR RELATION TO PHYSIOLOGICAL ALERTNESS VARIATIONS DURING LEARNING

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Abstract

In this study we explored whether physiological measurement technologies could be used in a combination with traditional educational research methods to investigate learning experiences. We aimed, first, to explore individual physiological reactions during learning and how these reactions relate to experiences, emotions and contexts of learning and, second, to test new methodology and its suitability for investigating learning.

The data was collected during a teacher education programme in a Finnish university. A total of 14 students participated in the study. The data was collected during two contact periods of three days and the weekends after them, ten days in total. We used a mixed method approach and collected various kind of data: quantitative heart rate variability data, qualitative diaries, videos, interviews and questionnaires. Heart rate variability data was analyzed by using SPSS, interviews were transcribed, and a content analysis was performed. Meaningful learning episodes and experiences reported by the students were linked to the physiological data. In addition to the heart rate variability analysis on sequential learning related activities, the heart rate variability between different days and periods was also conducted.

Overall heart rate variability varied between days and showed recovery during weekends. The daily differences in physiological alertness (derived from heart rate variability analysis) corresponded to the student reports, suggesting that small group work facilitated by the teacher was physiologically more alerting/engaging and also experienced as more meaningful than the lectures. In addition, comparisons between sequential activities with similar learning situations but with different contents showed differences in alertness. This may be due to subtle changes in the composition of the activities or students' physiological state. Exploring learning in natural contexts involves challenges, such as various uncontrolled variables in people's lives. Therefore further studies with larger samples, different contexts and meaningful episodes related more detail analyses are needed.

Keywords: learning experience, physiological measurement, adult learning, emotion, heart rate variability

1 INTRODUCTION

There is evidence that positive emotions may contribute to successful learning [1] and positive emotional experiences tend to be beneficial for adult learning [2]. Stress is known to influence learning performance and motivation and it would be important to investigate its mechanisms to gain knowledge for designing educational environments that promote learning and learner well-being [3]. Today's wearable measurement tools, e.g. quantified self –technologies, allow tracking of physiological indicators of physical activity, relaxation and well-being. In the context of education, there is an increasing interest towards learning analytics and especially for measuring learners' emotions and recognizing their role in learning [4] and teaching process [5], [6].

Learning is not just a cognitive process, but it includes also emotional elements and associated physiological reactions [2], [4]. Experiential learning situations have proven to be powerful in emerging emotional reactions. In experiential learning theory, emotional reactions are connected to so called learning experiences which disorient or surprise learner somehow. According to Malinen [7], this kind

of learning experiences, fractures, are necessary for personalized learning processes in the context of learning. Fractures are necessary for re-shaping and re-interpretation of earlier meanings and constructions, and for learning process as a whole. Fractures distort familiar and safe lifeline and mindset and are starting points for a critical and analytic phase with self-reflection of one's own way of thinking or doing [7].

In this research, we explore learning process with the underlying assumption that these fractures are meaningful learning episodes affecting emotions and physiological reactions. In fact, it might be especially these physiological and emotional elements that are critical for the entire learning process. Body physiology can be measured during learning situations for example with heart rate variability measures. We focus on learning experiences, emotions and physiological reactions of students who attend teacher education programme.

This programme has its theoretical basis in personalized learning processes and Experiential Learning Theory, a holistic theory of adult learning and growth [8], [9]. Shaping of experience is central in learning process (re-construction, re-organisation, re-defining, re-thinking, re-shaping etc.). Pedagogical studies for adult educators (PSAE) is a teacher education programme integrating students' independent work and studying together at campus at the core. It was launched in 2001 in the University of Jyväskylä, Finland. PSAE lasts 9 months, a full academic year, and gives participants a qualification and a formal licence to teach in the secondary and tertiary education levels. The module consists of nine contact periods of three intensive days held every four weeks. The structure of one contact period is described in Fig. 1. The starting point of learning is in students' own life history and work routines, as well as their working methods and mindset. The purpose is to develop a personal, reflective and analytical relationship to teaching and guidance. Crucially important is the support for personal development and critical reflection in cooperation with peers and teachers.

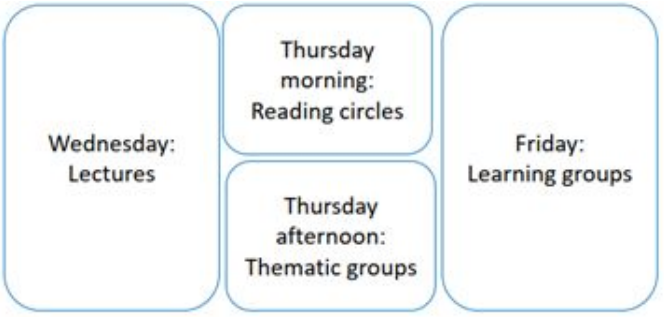

Figure 1. The structure of PSAE contact period.

During the contact periods, students participate in activating lectures (Wednesday), reading circles (Thursday morning, teachers not involved), thematic groups chosen by the student according to his / her own interest (Thursday afternoon, teachers involved) and learning groups (Friday, teachers involved). Between the contact periods, students engage in various experiential work assignments, such as recording their teaching experiments which include the element of 'doing differently than earlier'. These videos are shown to peers and teachers and discussed during the learning groups held on Friday (see Fig.1).

In this study, we aim to capture connections between psychophysiological reactions and meaningful episodes during the contact periods. Our project explores whether physiological measurement technologies can be used in the combination with traditional methods to investigate these phenomena – what happens in our body and mind during learning? We work as an interdisciplinary expertise team, covering adult and teacher education, neuroscience, psychology, cognitive sciences, and information technology.

We had two main research themes:

> ***What kind of individual psychophysiological reactions appear during adult learning and how these reactions are related to experiences, emotions and contexts of learning ?***

What kind of methodology is suitable for investigating learning episodes ?

2 METHODOLOGY

Data for this research was collected from two contact periods from PSAE, and a total of 14 voluntary students participated in the study among the permission approved by the University of Jyväskylä Ethical Committee. For data collection, we used a mixed method approach that focused on combining qualitative and quantitative data of the same episodes of learning process [10], [11]. We collected various kind of data: quantitative heart rate variability (HRV) data, qualitative diaries, videos, interviews and questionnaires. HRV data was collected with a device (Firstbeat Bodyguard 2) with electrodes attached to the participants' chests [15] for five days during two different study contact periods at intervals of four weeks. HRV is a physiological measure of variation between successive heart beats. It has been widely used as an indicator for autonomous nervous system activity (e.g., [12], [13]). In short, HRV, or HRV-derived indices of physiological state, can be used to identify intra-subject levels of stress and recovery or relaxation [14] by using algorithms to determine the involvement of parasympathetic and sympathetic nervous system . The measurement can be carried out in a natural situation unobtrusively and it does not interfere learning. The measurement devices were used by the participants (n=14) for both periods of total 5 days; three days during the contact periods and two days outside the study module. This allowed us to get the baseline of the participants' alertness levels more reliably than by measuring them only during the contact days. HRV data was analyzed with SPSS software by using a two-way ANOVA and paired Student's T-tests. In all SPSS analyses, students participating different learning situations were pooled into groups representing days, periods and/or learning situations. Some students were excluded from the analyses due to missing data. In this study, we used normalized 'Scaled Stress vector' provided by the Firstbeat company. The vector has been calculated from data cleared from outliers. The vector was computed from low-pass and high-pass filtered heart rate frequency data and respiratory sinus arrhythmia by using Firstbeat proprietary algorithms [15]. Reduction of HRV has been linked to stress, but it actually means high alertness, which is not necessarily due to stressful situation. For example, a lot of laughing and talking vividly can raise the alertness levels [16]. The students also filled diaries in which students marked sleep, dining, studying and leisure etc. In addition, we recorded several learning sessions. To identify the most meaningful learning episodes, each student filled a questionnaire form during an interview after the contact periods. After filling the questionnaires, the HRV data was linked to the reported meaningful learning episodes and learning sessions (See Fig. 2). The transcribed interviews, videos as well as the diaries were used to concretize the learning episodes during the contact days.

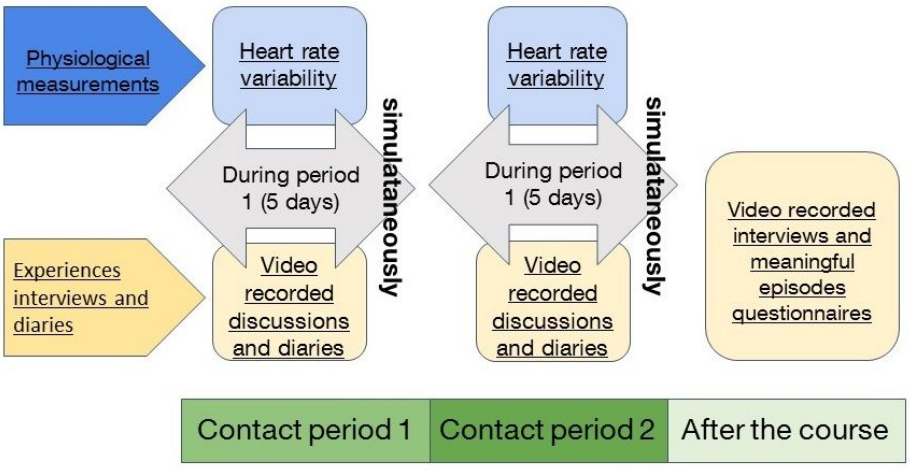

Figure 2. Data collection (n=14 students).

3 RESULTS

The following chapter presents the results comparing the two contact periods as well as selected learning sessions; lectures, reading circles, thematic groups and learning groups. The section 3.1 presents heart rate variability within and between the contact periods, the section 3.2 presents the

notes related to meaningful episodes and, finally, the section 3.3 presents differences between learning situations in which the relation between HRV variation and the meaningful episodes is examined by combining quantitative and qualitative data.

3.1 Heart rate variability within and between the contact periods

Based on the statistical analysis of the two contact periods during PSAE (n14), it seems that there were differences both within an individual contact period across separate days, and between the two 5-day contact periods between both teaching days as well as the two periods of five days. The simple HRV analytics suggested more stressful periods during teaching sessions of the first contact period (5 days) than the comparable teaching sessions during the second contact period (5 days). The HRV-based analytics also suggested more recovery periods during the last contact period. Especially during the first contact period Wednesday (1) and Friday (3) exhibited more signs of stress in the autonomic nervous system activity than Thursday (see Fig. 3). The highest alertness levels (HRV) were on Fridays (Learning group days). It is, however, noteworthy that also the "baseline" (i.e. Saturday and Sunday) show difference between the contact periods which should be taken into account when interpreting differences between period 1 and 2.

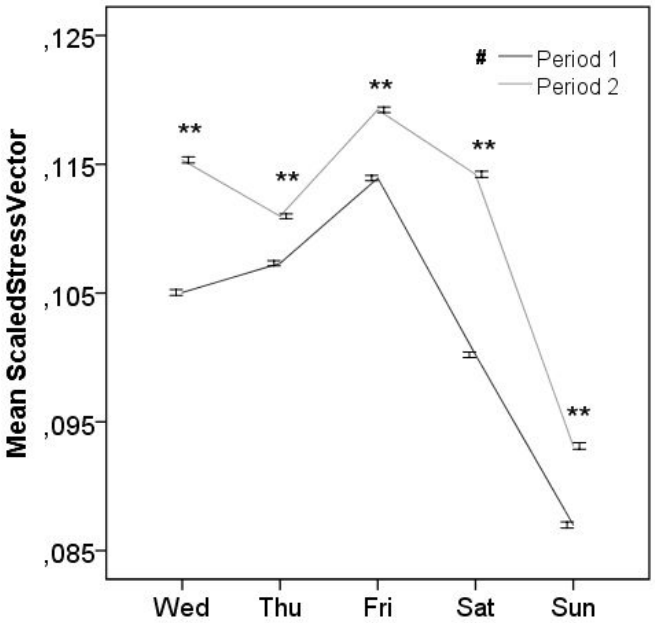

Figure 3. Comparisons of alertness describing scaled stress vectors from two PSAE periods show that differences are greater between the teaching days/sessions than between the months. Different days (**) and different periods (#) were significantly different. Error bars denoted 95% confidence limits. Y-scales were selected to emphasize that the stress vector activity variation follow the daily study curriculum regardless of the study period. (P<0.01, 2-way ANOVA with Bonferroni for pair-wise comparisons, N=14)

3.2 Meaningful episodes notes given to teaching sessions

In the interview sessions, the students identified what sessions they experienced as most meaningful ones during the two contact periods. Students filled the episodes notes into a form, and those notes were then summarized into Table 1.

Table 1. Meaningful episodes notes given by the students n=14

Learning sessions of the contact periods	***Contact period day***	***Meaningful episodes notes given by the students***
3 Lectures with group discussion	Wednesday	12

2 Reading circles	Thursday	19
2 Thematic groups with teacher	**Thursday**	**22**
2 Learning groups with teacher	Friday	18

Based on the amount of the notes given by the students, the thematic groups (teachers involved) were reported as the most meaningful episodes and the lectures as the least meaningful episodes.

3.3 Differences between learning situations

We selected individual learning situations for further analysis to study how does a) teacher (3.3.1) b) contact period (3.3.2., 3.3.4.) and c) content (3.3.3.) influence quantitative (HRV) and qualitative measures (see Table 1). The choices were based on possibility to compare situations with same participants and with flawless HRV data. We included comparisons in situations where the variables were either temporal (between contact periods) or content related. The following sections present both qualitative and quantitative results from the selected sessions. ***The hypothesis was that alertness (HRV) should be alike because the learning situation and participants were the same in each of these situations compared. The differences could thus be explained by the diversity of contents.***

3.3.1 The effect of teacher (and content): comparison between two lectures within the same contact period

We chose to compare two lectures held on first contact period by two different lecturers. The focus of the first lecture was in theoretic constructions of the main topic of the contact period. The participants described the lecture being 'ordinary' which they reported to mean that the content of the lecture was already familiar for many of them, thus it brought up hardly any new ideas or thoughts. The first lecture was described by one participant: "*I think it was a too ordinary lecture for me, and I have to say that I was a bit disappointed the whole time... I don't remember what was the point of the lecture*."

The second lecture was a narrative of the lecturer's personal life which was told plainly and vividly. The differing structure and style of the lecture seemed to divide the participants: some reported the lecture to provoke and arouse emotions of confuse while others enjoyed the idea of the lecture as a personal story. Another participant told about the second lecture: "*So that there were a lot of issues concerning counselling, you can say even principles of life which I remember*." The lecture was described with words such as **unusual**, **egocentric perspective**, **irritating**, **educative and concise**. The first lecture had higher alertness levels (stress) than the second lecture (Fig. 4).

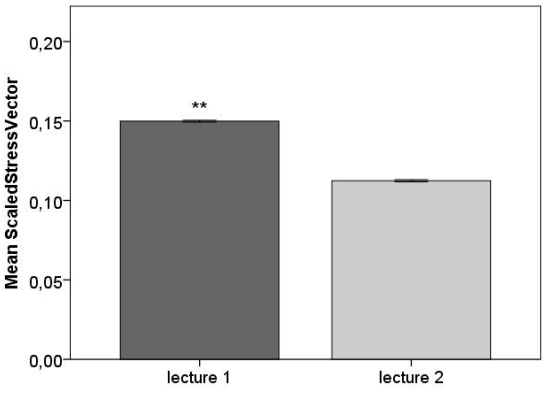

Figure 4. Two lectures - same group and period but different lecturers and content (paired Student's T-test, P<0.01, N=14). Error bars denote 95% confidence intervals.

3.3.2 The effect of the contact period: a comparison between the reading circles between the different periods

We examined also one reading circle (teachers not involved) during both contact periods. Three students were present during the first session and four students during the second session. The HRV

analysis was conducted to three same persons participating on both contact days (see Fig. 5). The students described the reading circles with words like ***enthusiasm, different opinions, good conversations, good atmosphere and important***.

One participant said: ”I always really liked the reading circles, and I got a lot out of them. She also continued: ”...good mood always ... it is calm and pleasant to be ... like in our reading circle.” Another participant characterized the atmosphere and the state of her alertness during the group work: ”I remember I had a pretty good state of alertness and it was so easy… I thought it was a really meaningful time in the reading circle… it was a good focus, able to focus and receive and refine thoughts…”

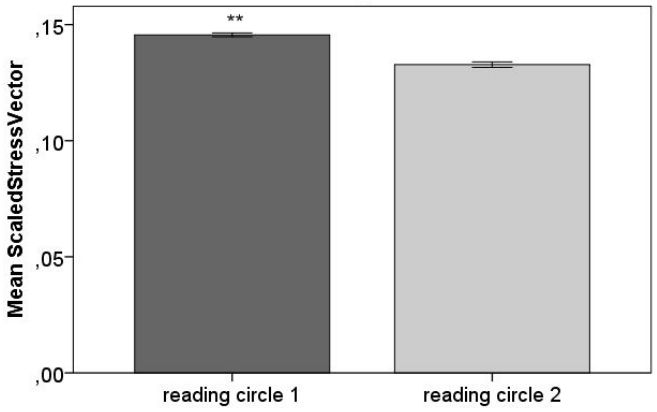

Figure 5. Two reading circles (teachers not involved) in the different contact periods. Reading circle 1 caused more alertness (stress) than reading circle 2 (paired Student's T-test, P<0,01, N=3). Error bars denote 95% confidence intervals.

As hypothesized, the results did not show clear differences between the two reading circles based on the interviews or meaningful episodes questionnaires filled. Based on statistical HRV analysis (see Fig. 5), however, there is a slight difference.

3.3.3 The effect of content: comparison between different thematic group sessions

We explored the Thematic group session held on the first contact period to compare whether there would emerge differences between the two varying tasks which students worked on that day. The thematic group was highly valued among all seven participants and it also ***received most meaningful episodes notes*** (see Table 1). It was described with words and phrases such as: **not just lazy babbling, unbeatable, educative, nice, always positive feelings**.

The focus in the beginning part of the thematic group was on a discussion of the participants' thoughts and conceptions of the theme of this thematic group. In the latter part, there were a dialogue task and a listening task. The discussion and the tasks were mostly seen as convenient. One participant reported learning from oneself after the listening task: “I was a bit surprised that I was such a good listener.” Another participant described the same task and learning from it: “It was a good learning experience … I still have a lot to learn.”

Based on the HRV results, the discussion contained more alertness (stress) than the tasks containing listening (see Fig. 6).

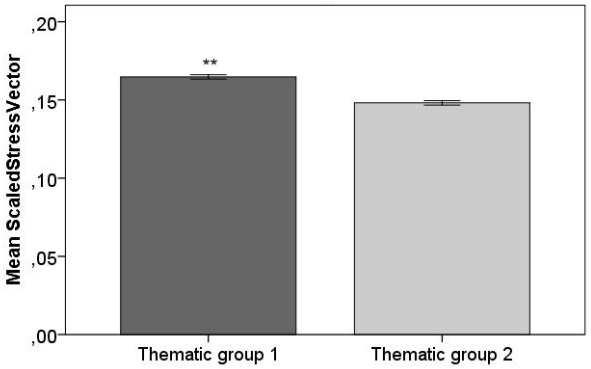

Figure 6. Thematic groups, comparison of HRV during the two different tasks conceptions of experiential learning (1) vs. listening task (2). (paired Student's T-test, P<0.01,N=5) Error bars denote 95% confidence intervals.

3.3.4 The effect of contact period: a comparison between the learning groups in the different contact periods

The last comparison made was between the structurally similar learning group sessions held by the same teacher during both contact periods on Friday. The difference between these sessions was that the students presenting their teaching videos were different on both time. The participants described these sessions very positively even though several of them mentioned that they were feeling very anxious when showing their own video and receiving feedback. In fact, watching and showing videos were described as the most meaningful episodes and very good learning experience. They used words like **very good experience, good atmosphere, best thing, getting to know each other** to describe the sessions.

One participant described that "watching other students performances (teaching on videos) and sharing experiences is interesting; giving feedback feels good". Several participants reported that learning group sessions were: "one of the best things during these studies." and one of them summarised well the core of the video sessions: "everyone else saw me as a teacher".

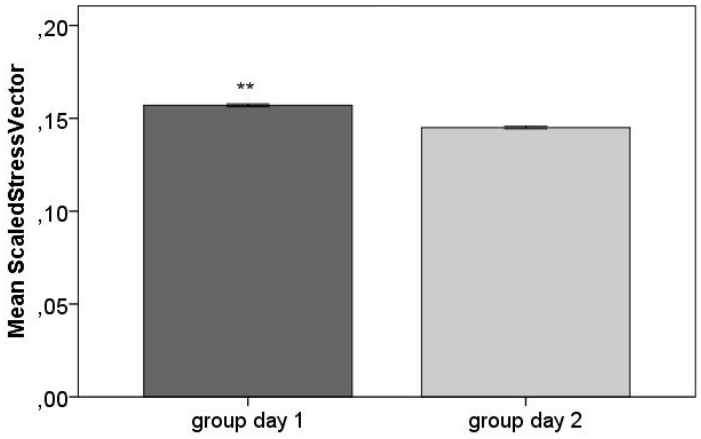

Figure 7. Two learning groups held by the same teacher (A) in the different contact periods (paired Student's T-test, P<0,01, N=6). Error bars denote 95% confidence intervals.

The HRV analysis showed that the learning group day 1 was more stressful than the learning group day 2 (see Fig. 7). The main content difference between the learning groups during on the different contact periods was that in the last part of the latter group session the students were given a task to design a spring festival program, about which they told they felt very positively and were enthusiastic to implement that as a team.

4 DISCUSSION AND METHODOLOGICAL CONSIDERATIONS

During the two contact periods of PSAE, there emerged differences both within an individual contact period across separate days, and between the two 5-day contact periods. Overall, the first contact period included more alertness (stress) than the second contact period which included more recovery, respectively. Wednesday and Friday included more alertness (stress) than Thursday. The thematic groups (teachers involved) were reported as the most meaningful episodes and the lectures as the least meaningful episodes based on the amount of the notes given by the students. Overall, the small group sessions gathered more notes compared to the lectures.

In addition, there were higher HRV results found in the small groups than in the lectures, even though the lectures also differed from each other. The students' HRV levels were higher in the first lecture than during the second lecture even though the first lecture was described as ordinary and that it did not provide any new information, which could have predicted boredom and lower alertness. There seems to be a discrepancy between alertness and reported emotions of irritation during the second lecture and the measured reduced physiological alertness shown in Fig. 4. However, these results might be explained also by the different teaching methods in the lecturers since the first lecture included discussions in small groups while the second lecturer was in charge of the speech for the most of the time and the students were only listening. The strongest variation between two learning sessions was found in the lectures in which the amount of the analysed data was highest. The lecturer was also another changing factor present in the lectures, so in this respect, the comparison of the two lectures was slightly different than with other learning situations.

Even though there were no clear differences between the two reading circles based on the interviews or meaningful episodes questionnaires filled, the statistical HRV analysis showed a slight difference. The HRV results may have been affected by the varying contents of the books under discussion. In addition, different students presented their books on each occasion further complicating the interpretation of the results.

Similarly, the first thematic group showed a larger HRV response compared to the second one. The comparison between the learning group days and the comparison between the reading circles also showed significant differences in HRV, but they were not corrected for the overall lower stress levels on the second period. The differences between the lectures and thematic group tasks could be also interpreted as increased fatigue towards the afternoon but together with the questionnaires and interviews they provide an additional source of learning contents related physiological information. For example, the discussion in the thematic group required concentration but the tasks containing dialogue and listening were more related to paying attention than intense thinking. There is no clear explanation on why HRV was higher in the group sessions involving the teacher compared to the lectures and reading circles. Yet, the intense atmosphere of the small group sessions in the combination with demanding content may result in higher alertness. In addition, the reason why the students gave more meaningful episodes notes to the small group sessions compared to the lectures could be explained with the safe and familiar atmosphere of the small groups.

Combining qualitative and quantitative data from learning situations introduces challenges. However, this pilot study showed that these can be implemented as described in Fig. 7. Questionnaires for background information should be meaningfully combined with interviews, videos and diaries and further into the physiological measurements. Especially, the synchronization of the qualitative data elements into time-varying quantitative data on millisecond time scale is challenging. Such triangulation can, however, provide invaluable, holistic insight into the process of learning.

Changes in HRV levels might be explained, for example, by tiredness or the avoidance of negative emotional events (eg., [17]). Due to our small sample size (N=14) and concentration on small group work (N=3), the results should be interpreted with caution. Furthermore, HRV data from the second period was consistently slightly lower than the first period. Nevertheless, the changes vary consistently reflected the daily activities, even across the study periods and the amount of gathered data, including the baseline, extended over 10 days providing reliability to the HRV data gathered from each individual.

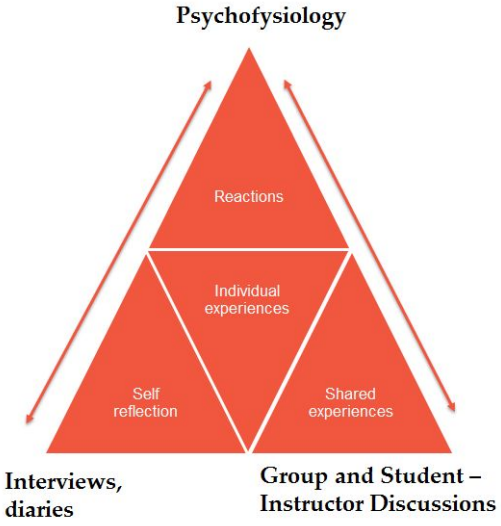

Figure 7. Combining data: physiology (HRV), students diaries, video recorded discussions and interviews were all needed to understand the phenomenon of learning.

5 CONCLUSIONS

This project explored whether physiological measurements, such as heart rate variability measurement technology could be used in the combination with traditional educational research methods to investigate adult learning. We had two research themes: First, to explore individual physiological reactions during learning and how these reactions are related to experiences, emotions and contexts of learning and, second, to test new methodology and its suitability for investigating learning.

The results suggest that alertness levels may vary between used teaching methods and learning contents. The qualitative data seem to give support to the quantitative analyses results. Even though the overall structure of the measured two periods was the same, differences were found. These preliminary results indicate that the differences of HRV might be explained by content specific issues. In addition, explanations can be found from the participants' daily life outside PSAE. Yet, there is some evidence showing that these results may indicate that varying contents, and even teachers, affect physiology, emotion and experience of learning.

Exploring learning in natural contexts involves challenges such as various uncontrolled variables in people's lives. In the future, HRV data could potentially be used in the realisation and planning of the curriculums, but further studies are needed. Our research team will continue with larger samples and in different learning contexts. We also aim at combining HRV derived from the periods of meaningful episodes in more detail to various learning situations and refining the analysis to even minute level. This pilot study demonstrated that it is feasible to gather physiological data to gain information on students' alertness levels related to learning. The first results also indicate that autonomic nervous system measures may relate to personal experiences, emotions and different contents of learning. Most of all, this first experiment showed that triangulation can be fruitful and will provide new approaches and multidisciplinary questions for further research.

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