Measuring Effects of Reflection on Learning: A Physiological Study

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Abstract: As an economical and feasible intervention, reflection demands learners using critical thinking to examine presented information, questioning its validity, and drawing conclusions based on the resulting ideas during a learning process. The aim of this study is to gain insight into the effects of practicing short, frequent and structured reflective breaks that are interspersed with the reading process of a learning material. It tries to reveal whether physiological signals can be used as appropriate indicators to reveal the actual changes of cognitive states while introducing different reflective breaks during learning. The recorded physiological signals include skin temperature, blood volume pulse, pulse volume amplitude, and pulse rate. The results show that while these embedded "reflection rituals" did not affect learners' performance they had significantly impact on time on task, perceived learning and those learners' physiological (cognitive) states. Physiological data returned significant differences between the reading and reflection activity. Measurements of temperature and pulse rate are lower when covering the course equipped with additional reflection affordances while blood volume pulse and pulse volume amplitude are higher. In addition, applying statistics analysis to the physiological data exhumes significant differences between different types of reflection activities for those measurements including skin temperature, pulse volume amplitude and pulse.

Keywords: reflective break, physiological signals, learning, reflection

1. Introduction

Today's teaching practice aims to educate the knowledge workers of the future how to master domain knowledge and develop transversal (domain-independent) skills. The latter enables individuals to cope with requests for acquiring new knowledge and ongoing personal development. As an economical and feasible intervention, reflection is often embedded into a learning process and demands learners using critical thinking to examine presented information, questioning its validity, and drawing conclusions based on the resulting ideas. At the same time, learning through gaming format starts to gain popularity since it makes good uses of a competitive mechanism that pits the learners against each other or provides challenges for learners in order to motivate them to learn better.

This paper probes two research topics in Gamed Based Learning: the effectiveness of physiological signals as indicators to monitor and correlate with the cognitive state during reflection and non-reflection period and the potential benefits of tidy frequent and structured reflective breaks interspersed with the reading process of learning material to advance such a student/professional development.

1.1 Physiological Signals and Learning

Scales or items referring to student workload or stress have commonly been recognized as an important variable in designing and proposing learning techniques. The major reason for measuring workload is to quantify the mental cost of performing learning tasks in order to predict learner performance. Mental workload can be affected by numerous factors that make it difficult to have definitive measurement. Physiological signals have been used by researchers as indicators of mental workload and stress for some time [Vicente, Thornton & Moray 1987; Wilson 2001]. Psychologists use physiological measurements as special identifiers of human emotions such as anger, nervousness, and sadness [Ekman, Levenson & Friesen 1983]. However, physiological data have not been employed widely to identify learners' experience states, such as engagement and reflection.

1.2 Reflective Breaks

John Dewey [Dewey 1966] has stated" We do not learn from experience. We learn from reflecting on experience." Reflective breaks have received attention from research when applied to face-to-face lectures [Di Vesta, Smith 1979; Ruhl, Hughes & Schloss 1987; Simpson 2004]. Despite the availability of theoretical models of reflection [Boud, Keogh & Walker 1985; Le Cornu 2009; Moon 1999] and a clear drift towards the promotion of thinking skills [Romainville 2007; Rychen & Salganik 2003], finding practical means to introduce the reflective habits to learners remains a challenge for researchers [Claxton 2006; Csap 1999] and practitioners [Jaschnik 2011; Joseph 2003]. Researchers and practitioners have identified that there are several types of reflection breaks:

1. **questioning**: previous research highlights the importance of encouraging students to generate questions about the study material [Logtenberg, van Boxtel & van Hout-Wolters 2011; Marbach-Ad & Sokolove 2000; Pedrosa & Moreira 2009]. In this study, students deliberately and systematically exerted a questioning strategy called "student set the test".
2. **evoking**: an evocation brings or recalls to the conscious mind what has been previously read. Conceptual works of the "mind management" theory [Brown-Frossard 2012; De la Garanderie 1989] suggest that this process of mental imaging allows readers to somehow transform what they have read into a mental object [Seel 2001; Vermersch 2009] and so doing to anchor it in their mind.
3. **self-assessing**: research shows that self-assessment can lead to significant enhancements in learning [Taras 2002] by developing students habit to evaluate the strengths and weaknesses in their own study.

2. Experiment Design

2.1 Research Questions

In this comparative study, we have formulated two research questions that guided the experiment design.

A. We assume that the biofeedback measurement can bring extra information about possible contrasts between distinct activities performed within the learning process. Therefore, the first question was whether the absence/presence of reflection amplifiers impacts upon the physiological measurements of the control/treatment group. Reflection amplifiers refer to deliberate prompting approaches offering learners brief episodes of thinking while studying [Verpoorten, westera & Sprecht 2011].
B. In this study, we incorporate all three types of reflection breaks to establish learning as an object of attention and reflection and, so doing, to introduce students to essential components of academic literacy. For the questioning type of reflection in this study, students deliberately and systematically exerted a student set the test strategy. Therefore, the second research question was whether different types of reflective amplifiers do not have the same impact upon the physiological measurements.

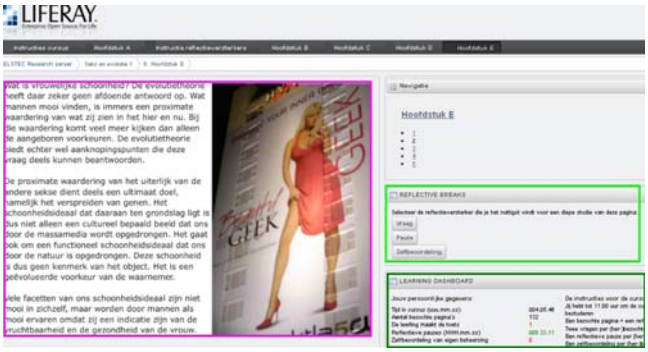

Figure 1. The page design bundles content (purple frame) and affordances to develop thinking habits: reflective breaks (light green) and learning dashboard (dark green).

2.2 Method and Materials

The course designed for this study was a shortened version (1H) of the 4-hour online course Seks en de evolutie (Sex and the evolution) created [Eshuis & Goltstein 2007] and offered in Dutch by the Open University the Netherlands. The course covered non trivial and interrelated notions and

mechanisms as defined by Darwin and his followers: reproductive value, paternity uncertainty, mating strategies, differential investment in parenthood, etc. The course invited learners to use this theory as an interpretation grid of gender-related behaviors observable in everyday life. The course consists of 5 chapters of 5 pages each, which contained about 200 words and one or two illustrations (Figure 1). In order not to bias the use of the different reflective breaks (see next section) by uneven levels of difficulty in the content, special attention was paid to ensure equivalence between all chapters. Each of them underwent the Flesch reading ease test [Flesch 1948] which returned an average comprehension difficulty level of 52 (SD = 4), which is comparable to the level of the Time news magazine. In addition, a systematic concept mapping procedure of each chapter ensured that they presented an even level of complexity regarding the number of new concepts introduced.

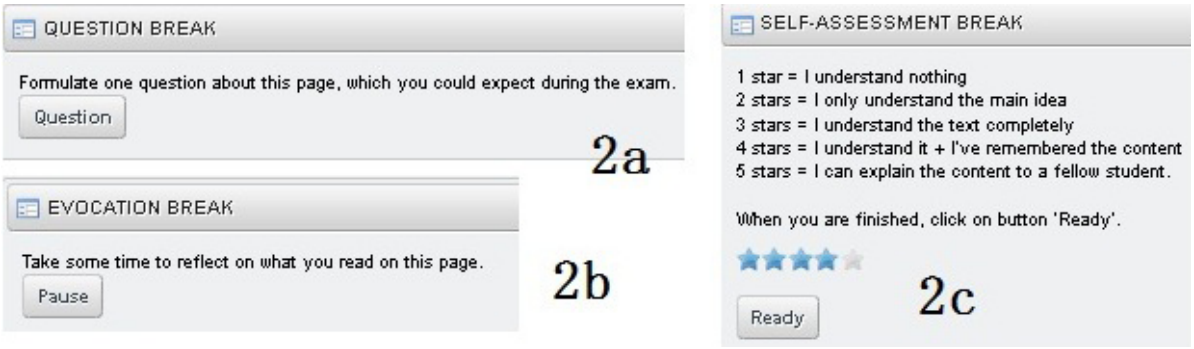

Figure 2. The reflection portlets: question (2a), evocation (2b), self-assessment (2c).

The online course was delivered in the study at 2 different conditions: with and without reflective breaks (RBs). The study exposed participants to 3 types of RBs: questioning, evoking and self-assessing. To support and condense the reflective processes of questioning, evocating and self-assessing, 3 miniature Web applications (called portlets on the Liferay platform) were developed (Figure 2). They displayed, in a clear and graphical style.

1. The Question break portlet offered a note-taking tool where the students wrote down their questions (Figure 2a).
2. The Evocation break portlet combined a “starts the evocation” button and a “stop the evocation” button (Figure 2b).
3. The Self-assessment break portlet presented as a 5-star visual scale (Figure 2c) that the students used to indicate their current level of mastery of a defined portion of content (for each level a standardized explanation was given).

Table 1. Compact view of the course chapters with offered reflective breaks

Course chapter	Question breaks	Evocation breaks	Self-assessment breaks
1	-	-	-
2	Yes	-	-
3	-	Yes	-
4	-	-	Yes
5	Yes	Yes	Yes

During the study, the treatment group studied chapter 1 just like the control group: without any reflective break. This arrangement opened to participants a possibility of contrast within the learning experience and provided an internal yardstick to the chapters studied with support tools. In chapters 2-3-4, students got acquainted with one reflective technique (see Table 1). In chapter 5, all techniques were available. Based on their experience in the previous chapters, students could decide which one to use after each visited page. The students had to deliberately practice the offered RBs after each page visited or re-visited. In order to consolidate this systematic reflective approach, a learning dashboard (Figure 3) was set up. It contained a built-in reminder of the importance to practice the

reflective breaks. A color scheme indicated whether or not the number of (re-)visited page matched the number of use of the RBs. In case of match, the number appeared in green and in case of discrepancy in red.

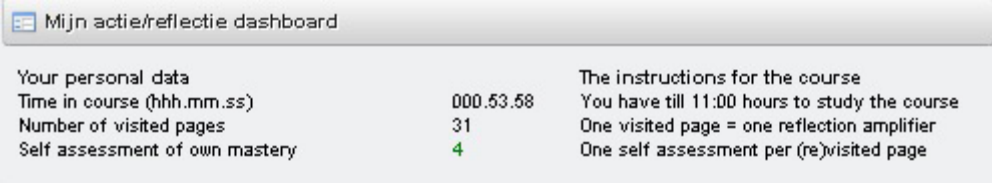

Figure 3. The learning dashboard for chapter 4; In green, the number 4 mirrors that the student practiced self-assessment each time he/she visited a page of this chapter.

2.3 Physiological measures

Physiological data was collected with the appliance Biofeedback 2000 x-pert from SCHUHFRIED (Figure 4). This non-invasive biofeedback system recorded the following physiological signals: a) skin temperature (TEMP), b) blood volume pulse, viz. the pulse component of the surface blood flow (BVP), c) pulse volume amplitude, viz. the amplitude of the blood volume pulse (PVA), and d) pulse rate (PR). The sampling pace was one measure every 25 milliseconds (Figure 5). The learning sessions of the students were also screen-recorded with the software Camtasia in order to grab supplementary information about the sequencing of reading and reflecting periods.

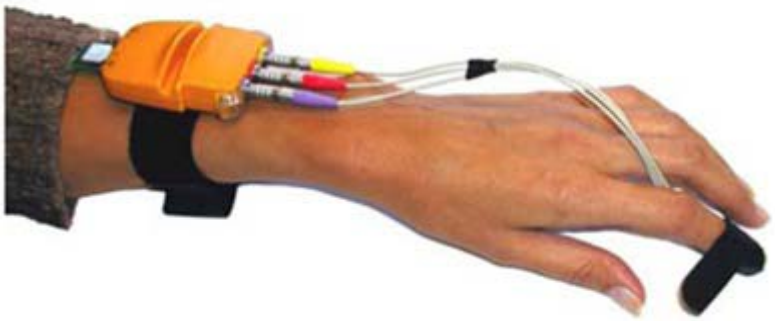

Figure 4. During the experiment, the module is fastened with Velcro strap to the index finger of the non-dominant hand.

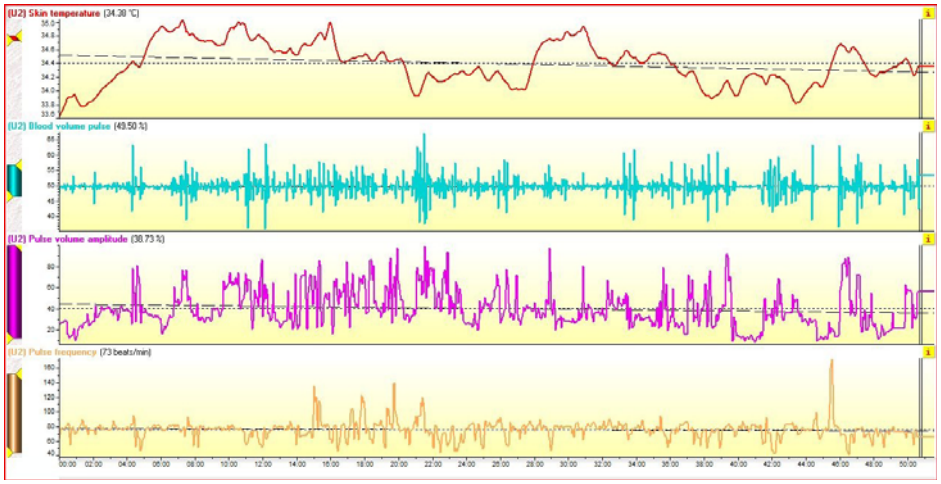

Figure 5. Visualization of the 4 measured physiological signals for one subject (treatment condition).

2.4 Procedure

Participants received a 15 euro iTunes voucher for their participation and were debriefed before leaving. Taken prior to the course, the background questionnaire evaluated the students' pre-knowledge of the course topic with 6 multiple-choice questions. Meta-cognitive ability was assessed for each student by their teacher on a 3-item Likert scale. After a pre-test, participants individually studied in one version of the course (with or without reflection breaks) according to a random

distribution. Both groups were evenly invited to practice a thoughtful study freed from time pressure in order to gain as much mastery as possible of the learning material. The tracked data was the time in the course (total and per chapter), the number of pages visited (total and per chapter) and the number of time a reflective break was used. The logs also stored the choices made by learners in chapter 5 regarding the reflective breaks. After the course completion, students filled in a post-test. This questionnaire gathered:

a) **Evaluative feed-back**: open and closed questions collected students' perceptions of overall satisfaction, sense of control, and feeling of learning. Questions relating to the instructional intervention were added for the participants to the treatment group.
b) **Performance measures**: a test assessed the knowledge and comprehension. Ten multiple choice questions were selected among a pool of questions tested by 137 students in a previous experiment based on the same study material. The discrimination index was of .67 in average. For this index, values above 0.4 are desirable [McAlpine 2002], which located the test at a medium-high level of difficulty. Three open questions asked students to comment on pictures with what they learned in the course. This was consistent with the design of the course that displayed carefully selected pictures on each page.

A follow-up questionnaire was administered one month after the experiment in an attempt to evaluate possible persistent effects. The follow-up questionnaire asked students to give to an imaginary friend who ought to take the same course some advice regarding 8 study strategies, including the 3 reflective breaks. The perceived relevance of the strategies was rated with sliders on 100-point scales, an asset available on the survey software Qualtrix.

3. Results

The experiment convened 42 subjects at the same time. The sample population consisted of secondary-school students physically present in computer rooms during the experiment. In that sense, the context of this study was close to regular schooling practice. It sought to provide more stable experimental conditions, more homogeneity in the sample and a contrast regarding the target audience of the reflective breaks. The data collected were the returns from the questionnaires (pre, post, follow-up), the logging data and the physiological measures. Students who missed either the pre or the post questionnaire were removed from the analysis. It was the case for 2 participants in the treatment group. 40 test persons (mean age = 17 years old, 37% female, 63% male) composed the final sample: 21 participants in condition 1 (control) and 19 in condition 2 (reflective breaks).

Table 2 Results for the physiological signals in with/without reflection amplifiers condition between the control and treatment groups)

Results	Mean	Standard deviation (SD)	
TEMP with RBs	33.65	1.05	p< 0.02
TEMP without RBs	30.98	3.12	
BVP with RBs	49.37	12.35	p<0.02
BVP without RBs	49.52	13.04	
PVA with RBs	31.18	19.57	p<0.02
PVA without RBs	34.53	24.8	
PR with RBs	68.69	12.74	p<0.02
PR without RBs	60.11	12.85	

3.1 Physiological data

Physiological data was collected from 4 students (2 at the control group without reflection breaks and 2 at the treatment group with reflection breaks) because limited amount of physiological sensors are available. T-tests were conducted on 130773 paired sampled measures to compare TEMP, BVP, PVA and PR in the "with and without reflection breaks" conditions. This returned significant differences for the 4 physiological signals (Table 2). TEMP and PR are lower when covering the course equipped with

additional reflection affordances while BVP and PVA are higher. The accuracy of the measure is acceptable (the observed difference in temperature is far above the variations that could be imputed to the recording system (0.01C) and the other measures embed compensations for interference and automatic averaging of data at baseline).

Table 3. Mean and SD of the physiological signals with different reflection amplifiers.

	reading	questioning	evoking	self-assessing
TEMP (mean)	33.350	34.055	33.722	33.634
(SD)	1.193	0.590	0.717	0.641
BVP (mean)	49.334	49.441	49.389	49.503
(SD)	11.184	17.524	11.276	9.442
PVA (mean)	28.415	45.817	26.190	24.146
(SD)	17.928	25.509	15.747	11.702
PR (mean)	66.893	68.721	70.912	64.874
(SD)	11.553	17.096	12.383	8.562

In order to refine the analyses, the screen recordings of the learning session from the subjects in the treatment group were analyzed to identify reading versus reflection periods. According to this timing information, the sampled physiological measures matching respectively each category were put together. Applying One-Way ANOVA also exhumed significant differences ($p<.0005$) for the 4 physiological signals but with a slightly different pattern: in the periods of structured reflection (use of the reflection amplifiers), TEMP, PR and PVA are higher while BVP is lower (Table 2). Following the same process, the sampled measures corresponding to the periods of use of the different types of reflection amplifiers were contrasted against each other and with the reading activity (Table 3). Applying One-Way ANOVA exhumed significant differences for three signals except BVP ($p < .002$).

3.3 Time on task

Total time on task (Figure. 6) was descriptively higher in the group prompted to reflect (M = 52 min, SD = 9 min) than in the group without prompting (M = 26 min, SD = 12 min), and the difference was significant, $t(38) = 7.46$, $p < .0001$, $d = 2.45$.

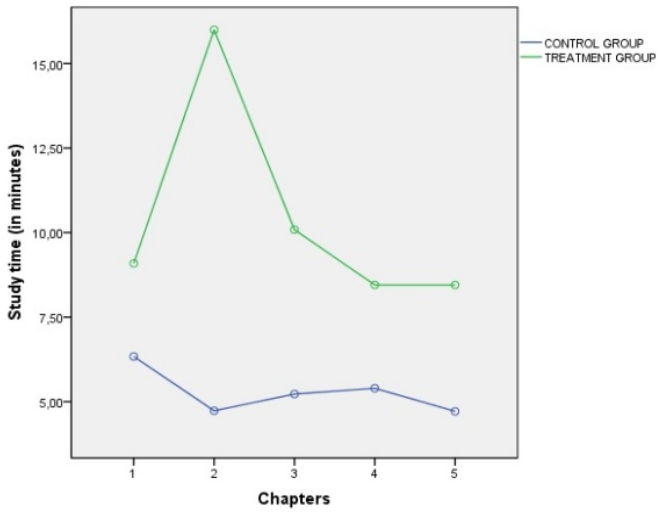

Figure 6. Average time (in minutes) per chapter for the control and the treatment group

3.2 Performance

Scores for the multiple-choice questions revealed no significant differences between the control group (X = 4.5, SD = 2.24) and the treatment group (X = 4.7, SD = 1.59), $t(38) = .41$, $p = .67$, $d = .08$. A 3-level scoring rubric was used to control the quality of the answers to the open questions:

- trivial explanation of the picture;
- explanation invocating the correct Darwinian concept;
- explanation contextualizing the correct Darwinian concept in the overarching evolution theory.

The treatment group (X = 4.5, SD = 1.6) did not perform differently from the control group either (X = 3.7, SD = 1.7), t (38) = 1.54, p = .13, d = .05.

3.4 Feedback from learners

73% of subjects in the treatment group claimed that their learning experience in the course differed from their daily experience against 61% of subjects in the control group (relative percentages). Results showed that each of the 3 reflective breaks was foreign to about half of the sample population (Figure 7). 16% of the respondents answered almost never for all 3 reflective techniques.

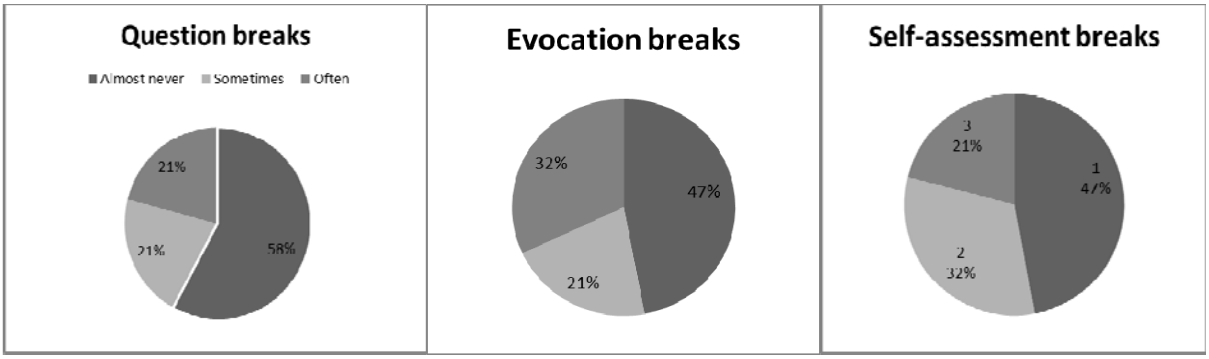

Figure 7. Familiarity level with the reflective breaks prior to the experiment.

3.5 Perceived effect on time and mindfulness

The reflective breaks were rated by the students on a 3-point Likert-type scale for their contribution to their study result and study time (1 = decreased the quality of my study/my study time, 2 = did not affect the quality of my study/my study time, 3 = increased the quality of my study time). Figure 8 illustrates the results.

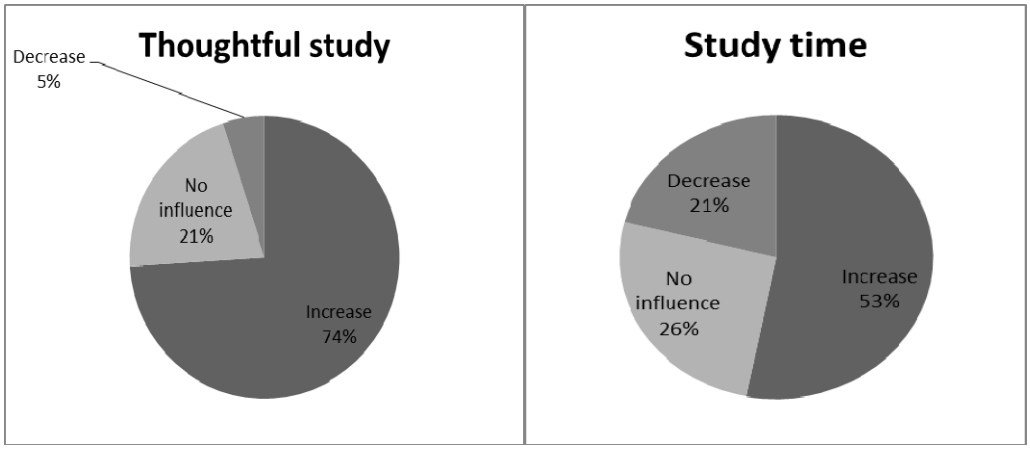

Figure 8. Perceived contributions of the reflective breaks to study quality and time.

4. Discussions

In this study, we observed that physiological measurements differ between the conditions both at the global level of the course and when reading/reflection periods are contrasted. The observed variations indeed bring extra information to the study of reflection in formal learning. So far, reflective activity attached to this context has usually been inferred from performance changes or claims of students (scales, open questions) or think-aloud protocols [Veenman, Van Hout-Wolters & Afflerbach 2006].

What we have learned here is that biofeedback measurements can be another dimension to the study of the phenomenon of reflection during learning. The findings of this study suggest that the cognitive states associated to different learning activities may be detected and recognized from physiological parameters. For instance, the externally-imposed reflection remits seems to trigger internal responses traceable in physiological data. However, interpretation of these findings is not straightforward. It is not clear whether reflection is assimilated to some forms of mediations, which can slow down certain body activities. Or on the contrary, reflection reverberates as a form of stress [McCraty, et al. 1999] because of its compulsory (this is an assignment) or/and perhaps unfamiliar character, which has effects on some physiological signals.

Answering these questions goes beyond the scope of this study. It would require further interdisciplinary discussions combining both pedagogical and psycho-physiological expertise. But, the findings related to the physiological measures in this paper should nevertheless be taken with prudence for the following reasons:

a) the results bear on a limited number of subjects with physiological measurements,
b) the huge amount of sampled observations can partly cause the significance.

It calls for further investigation into the relationships between reflection and learning performance through physiological measures that would be carried out with larger samples and with contrasted audiences of low and high performers in order to confront the way they study and practice reflection to their respective physiological coherence.

5. Conclusions

Reflective break means to induce regular mental tingling for evaluating ones own learning, nurturing internal feedback [Butler & Winne 1995] and maintaining active commitment to the tasks at hand. This study has explored the potential benefits of reflective breaks for learning activities. The study also investigates whether physiological signals can be used as appropriate indicators to detect the actual changes of cognitive states while introducing reflection breaks during learning. The pattern of findings suggests that the benefit of a one-hour hand-on session embedded with the reflective strategies is not significant in terms of enhancing cognitive performance. However, these reflective practices did bring an increased awareness and intensified their presence to the learning process. This study has demonstrated a physiological method that can be used to study the effects of reflection on learning. The study points out the future challenges faced by researchers while studying reflective break with physiological signals.

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