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WE-COLLAB

PR 5: Cognitive and emotional assessment of learners

BrainSigns (01/04/2023 – 31/07/2024)

According to the WE-COLLAB project proposal, and coherently with the objectives of the project itself, BRAINSIGNS performed 4 main tasks along the timeframe:

1. Literature review to identify the more relevant cognitive and emotional dimensions investigated so far, the most used tools and the experimental settings;
2. First experimental study to apply the neuroscientific approach and demonstrate its effectiveness in comparing different educational contents;
3. Second experimental study (a pilot study performed during the training week hosted in Copenhagen) to deploy the developed neuroscientific approach to evaluate whether a different storytelling of the same educational content (in particular a video) could impact on the students' experience;
4. Third experimental study, actually the proof-of-concept of the WE-COLLAB project, where the neuroscientific approach has been deployed together with the Students Feedback App (result of the PR1) to evaluate remote and in-presence classrooms on the basis of the cognitive and emotional experience of students. The evaluation has not to be intended as an assessment of the single student, but as an assessment of the investigated variables (in this case remote and in-presence classrooms) on the basis of aggregate data.

The three experimental studies engaged in a total of 24 participants, all university students.
Here below, the main results for each of the aforementioned tasks will be reported and discussed.

1. LITERATURE REVIEW

The review aimed to examine prior studies on cognitive and emotional aspects relevant to evaluating the student experience. The main goals were:

- Identifying the key cognitive and emotional states of interest.
- Determining whether studies were conducted in real environments (e.g., classrooms) or artificial settings (e.g., laboratories).
- Analyzing the types of tasks and materials used in these studies.

The review considered a total of 47 studies, so in the following all the metrics in percentage have to be considered with respect to the total number of studies.
In terms of cognitive states, a lot of different aspects have been considered, sometimes with similar meaning but different names. To simplify the scenario, the different mental states mentioned by the considered studies have been grouped into two main cognitive processes: Attention, including

concepts as concentration, selective attention and vigilance, and Cognitive load, including concepts as mental workload, cognitive effort and mental engagement. Attention is essential for learning, since it is positively correlated with learning, memory, and recognition capability. Proper attention recovery methods can help restore attention during the learning process, thereby improving learning effectiveness. Cognitive load theory emphasizes the importance of balancing intrinsic, extraneous, and germane loads for effective knowledge acquisition.

Also in terms of emotional and affective states, different terms are used in literature, such as stress, motivation, frustration, arousal. Stress was predominantly studied under three categories: damage/loss (40%), threat (30%), and challenge (30%). Motivation was strongly linked to learning outcomes, particularly in game-based and interactive settings.

The majority of studies (approximately 65%) were conducted in controlled laboratory environments, highlighting a gap in real-world classroom applications.

Multimedia-based tasks (e.g., videos with integrated text) accounted for 50% of all tasks.

Physiological monitoring tools (e.g., EEG) were employed in only 20% of the studies to measure attention and cognitive load, thus pointing out a lack of know-how in terms of neuroscientific tools.

In particular:

a. Attention:

- 20 studies focused on attention, categorized as selective (40%), divided (30%), and sustained (30%).
- Real-world environments accounted for 25% of these studies, while 75% were laboratory-based.
- Tasks often involved multimedia (50%) or text-based exercises (35%), with 15% using physiological measures (e.g., EEG).

b. Cognitive Load:

- 15 studies analyzed cognitive load, divided into intrinsic (40%), extraneous (35%), and germane (25%).
- Laboratory settings dominated (80%), with only 20% conducted in classrooms.
- Common tasks included problem-solving activities (45%) and digital learning modules (35%).

c. Emotional States

- 12 studies explored emotions such as happiness (30%), stress (40%), and motivation (30%).
- A balanced distribution was observed between real-world (50%) and laboratory environments (50%).
- Tasks frequently involved feedback-driven interactions (60%) and game-based learning (25%).

Conclusion

This review highlights the importance of integrating cognitive and emotional factors into educational research and practice. A significant gap exists in translating findings from laboratory settings to real-world classrooms. Future work should aim to expand real-world investigations and explore innovative, ecologically valid methodologies. Along the WE-COLLAB project, the neuroscientific methodologies have been ecologically used through wearable devices to evaluate students' experience in three different applications.

2. COMPARISON OF CONTENTS

The study involved 10 participants from Sapienza University, evaluating their cognitive responses to three educational materials on the same topic. The materials included an educational video (Task A), a traditional training video with powerpoint slides and narration (Task B), and a text-only format (Task C). Neuroscientific tools, including electrooculography (EOG), photoplethysmography (PPG), and electrodermal activity (EDA), measured eye blinking, cardiac activity, and skin sweating, respectively. Participants engaged with each format, and neurophysiological signals were consistently recorded. The study aimed to identify differences in attention and engagement across educational types, reflected in neurophysiological responses. Participants completed content-focused questionnaires and qualitative inquiries on learning material quality.

In terms of ocular parameters, significant effects have been measured in terms of both Eye Blink Rate and Duration. Eye Blink Rate in particular is considered one of the most powerful biomarkers of attention, with an inverse correlation with it. Notably, the text (Task C) exhibits the highest values of inverse EBR, i.e. Attention, followed by the educational video (Task A) and the powerpoint presentation (Task B). Concerning the Eye Blink Duration (EBD), the Task C appears to be associated with higher EBD values. Notably, the analysis of EBD for Task A and Task B, both video formats, indicates reduced blink durations, particularly in the highly dynamic and information-rich Task A. This pattern aligns with the findings of studies proposing blink waveform parameters, including blink duration and prolonged closure durations, as indicators for predicting drowsiness and diminished performance.

Within the domain of physiological responses, distinct patterns emerged when observing the Heart Rate (HR) and the Low Frequency/High Frequency Heart Rate Variability (LF/HF HRV), with a statistically significant effect ($p < 0.05$) in terms of HR. HR, that is usually correlated to mental engagement and effort, achieved the highest values in correspondence of the text (Task C).
No significant effects have been found in terms of EDA, widely accepted as a biomarker of physiological arousal.

In analyzing questionnaire data, responses were systematically categorized by instructional materials, revealing notable disparities. Task C (text reading) exhibited a 44% error rate, surpassing Task A (22%) and Task B (28%). Qualitative assessments encompassing comprehension, memorization, attention, interest, and engagement favoured Task A across all aspects. Task A received positive responses from 70% for comprehension ease, 68% for memorization, and 74% for attention, outperforming Task B and Task C. Interest levels were highest for Task A at 81%, while Task B and Task C scored 59% and 38% respectively. Engagement with the narrative technique showcased Task A's superiority, with 84%, compared to Task B (53%) and Task C (36%).

The comprehensive findings unequivocally endorse Task A's pedagogical superiority in multiple dimensions, emphasizing its significance in cognitive performance and learning experiences.
In conclusion, participants exhibited greater difficulty with the textual material, as evidenced by lower scores in both performance and experiential quality. This difficulty indicates a heightened cognitive effort required for engaging with textual content.

The investigation delves into the realm of qualitative assessments and performance-based questionnaires, revealing that participants found the textual material to be the most challenging.

3. EVALUATION OF THE LESSON “STORYTELLING”

The study aimed to evaluate students' cognitive and emotional experiences while watching two educational videos of the same content ("Politeness and Communication") but of different lengths. The experiment was conducted during the training week at Copenhagen Business School to demonstrate how neuroscientific tools can assess learners' reactions to varying educational materials.

- Participants: 5 students (3 males, 2 females).
- Videos:
    - LONG: Duration 11 minutes and 30 seconds, including 27 slides with more text.
    - SHORT: Duration 5 minutes and 20 seconds, including 15 slides with fewer details.
- Equipment:
    - EEG (Mindtooth Touch) for brain activity.
    - PPG and EDA (Shimmer3) for heart and skin responses.
    - A final questionnaire consisting of 10 questions.

From the neurophysiological data 4 different neurometrics, i.e. synthetic measures of a specific mental/emotional state, have been computed, according to what arisen from preliminary scientific literature: Mental workload, Motivation, Attention and Emotion.
Both videos were cognitively engaging, with workload levels above baseline. The LONG video demanded more mental resources after the initial 3 minutes.
Also, the LONG video increased motivation and interest toward the end, attributed to more dynamic content and new slides.

At the same time, the LONG video captured higher attention initially, likely due to the greater number of slides and textual content. In any case, tables required more attention regardless of the video length.

Emotional engagement with both the videos was highest at the beginning, reflecting curiosity, but decreased over time due to relaxation. The final participatory example in the LONG video boosted emotional engagement again.

In terms of learning “performance”, students answered more questions correctly after watching the LONG video, suggesting better learning outcomes.

To summarize, the LONG video, despite requiring more mental effort, resulted in greater appreciation and better performance. Effective narrative and a balance between duration and information density are crucial for maintaining engagement. Neuroscientific tools can offer valuable insights for tailoring educational content to enhance student learning.

In conclusion, the findings highlight the potential of neuroscientific approaches in developing student-centered educational models. They allow for tailoring lessons to students' cognitive and emotional capacities, optimizing both engagement and learning outcomes.

4. COMPARISON OF REMOTE AND IN-PRESENCE CLASSROOMS

The study aimed to compare students' cognitive and emotional experiences during in-person and remote lessons, using the same teacher and content to eliminate bias. The goal was to assess the impact of these modalities on mental workload, attention, and emotional engagement, with the potential to enhance learning analytics.

- Participants: 6 students attended 4 lessons within the "Lingua Spagnola" course; 3 students attended 1 lesson within the "Bioingegneria" course.
- Lessons: 30 minutes in length, delivered by the same teacher in both in-person and remote formats.
- Equipment:
    - EEG (Mindtooth Touch) for brain activity (neurometrics of: mental workload, attention, and stress).
    - HR and EDA (Shimmer3) for heart and skin responses (neurometrics of emotional arousal and engagement).
    - WeCollab Feedback App for collecting students' real-time feedback.

In terms of results, remote lessons induced significantly higher workload, suggesting greater difficulty in learning and memorizing the provided information.
Higher distraction levels were observed during remote lessons, indicating that increased workload did not equate to better engagement.

In-person lessons caused higher stress, particularly at the beginning, possibly due to social or environmental factors. At the same time, emotional arousal was similar across both modalities, with minor differences in Skin Conductance Level (SCL).

The emotional arousal (a combination of SCL and Heart Rate) showed no substantial variation between in-person and remote formats.

Explicit feedback from students (collected through the WeCollab Feedback App) included comments like "slower" and "explain" reflecting difficulties in following the teacher.

It has to be noted that the app was not seamlessly integrated into the learning process, as students prioritized using laptops or phones for other tasks. Sparse and inconsistent feedback limited its correlation with neurophysiological measures.

In conclusion, neurotechnologies provide objective insights into students' learning experiences. In-person lessons may induce higher stress but enable lower distraction compared to remote settings.

Remote lessons, while cognitively demanding, may need better engagement strategies. The Feedback App requires significant improvements to be effective and user-friendly.

CONCLUSIONS

All these findings underline the importance of tailoring educational strategies to each modality, leveraging neurotechnologies to optimize lesson design and enhance student engagement in both in-person and remote environments. In particular:

- Neurotechnologies are a powerful tool to get objective information about the students' experience
- The advantage of this information is to be available online and eventually synchronous with specific events
- They can be translated into relevant KPIs, i.e. learning analytics, to be applied at different levels of education: evaluation of materials and contents, of education modalities, of lessons design, etc.
- It is still difficult to integrate them with other analytics (e.g. Feedback App), to understand how to integrate them in a different way.