Investigating Interpersonal Problem-Solving Activities via EEG Hyperscanning

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- This study aimed to observe brain-to-brain coupling in problem-solving discussions using EEG (Electroencephalography) hyperscanning.
- Six problem-solving questions included the disciplines of Mathematics, Computational Thinking, and Visuospatial Working Memory.
- Five neurophysiological indices to be extracted were engagement ($\beta/(\theta + \alpha)$), workload (θ_{Fz}/α_{Pz}), emotion level $\ln(\alpha_{F_4}/\beta_{F_3})$, acoustical events, and eye movement synchrony.
- We found out that the mean value of the index was lower for the less difficult questions. Also, the mean value of time and workload for each group showed an extreme positive correlation by the Question Dart.
- This research provides some direction for developing real-time feedback indices in the future.

01 Introduction

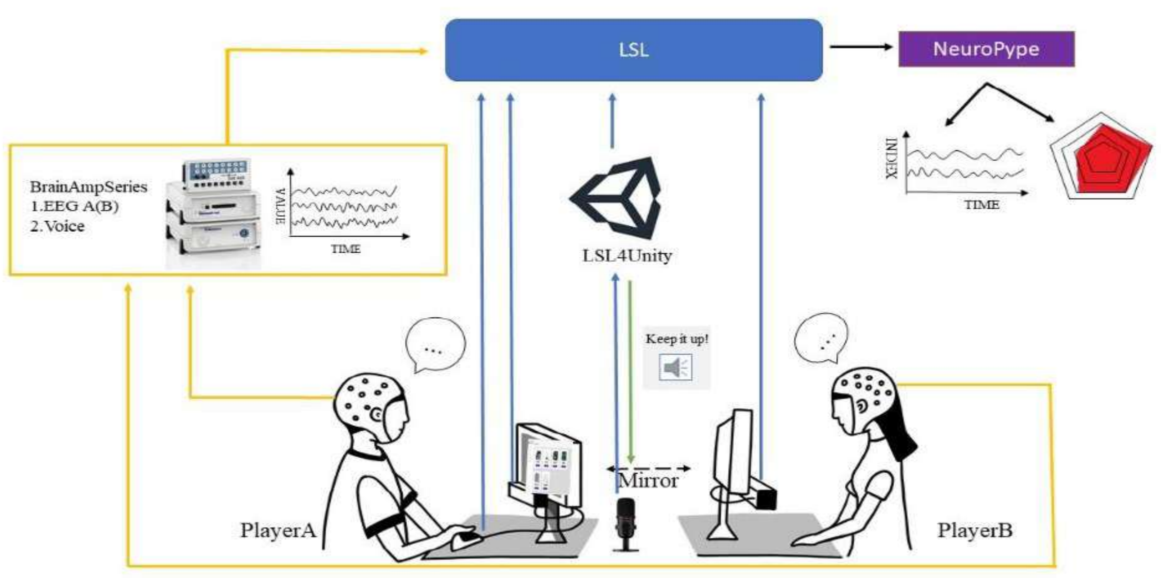
Communication and problem-solving are vital human skills, and they are also classified as 21st century skills. Previous study has shown that Mathematical mindset theory increases motivation, even when participants are not aware of mindset theory (Daly et al., 2019). Berka et al. (2007) found out that EEG workload increases with increasing working memory load and during problem solving, integration of information, analytical reasoning, and may be more reflective of executive functions. Costanzi et al. (2019) suggests that emotions enhance spatial memory performance when neutral and emotional stimuli compete with one another for access into the working memory system.

Table I. Five indices extracted to analyse interpersonal problem-solving activities.

	References	Channel	Indices
Engagement	(Coelli, Sclocco et al. 2015) (Prinzel, Freeman et al. 2000) (Safri, Sha'ameri et al. 2018)	- F4,F3,F7,F8 - Pz,P3,P4,Cz - Pz,P3,Fz,C3 - Pz,P4,Fz,C4	$\beta/(\alpha+\theta)$; β/α; $1/\alpha$; θ (time)
Workload	(Borghini, Aricò et al. 2015) (Di Flumeri, Borghini et al. 2018)	Fz,Pz	Fz θ/Pz α
Emotion	(Coan et al., 2003)		Frontal Asymmetry Index = ln (α power right F4 / β power left F3)
Level of discussion			
Synchronization of Eye Movements			

02 Methods

Ten dyads of experiments were collected (N=20, aged ~21). The task required participants who are familiar with each other to discuss and solve six problem-solving questions, including Covid (probability), Dart (Common Factor), Change (Reckoning), Hanoi Tower (Recursive Relation), Bridge (Logical Reasoning), and Turn (Working memory). The participants were encouraged to interact verbally with each other. If the participants did not speak for a certain time, the system would give an immediate feedback, encouraging them to speak up. As players discussed and answered, we collected their brainwaves, eye movements, sound frequencies, and mouse tracking.



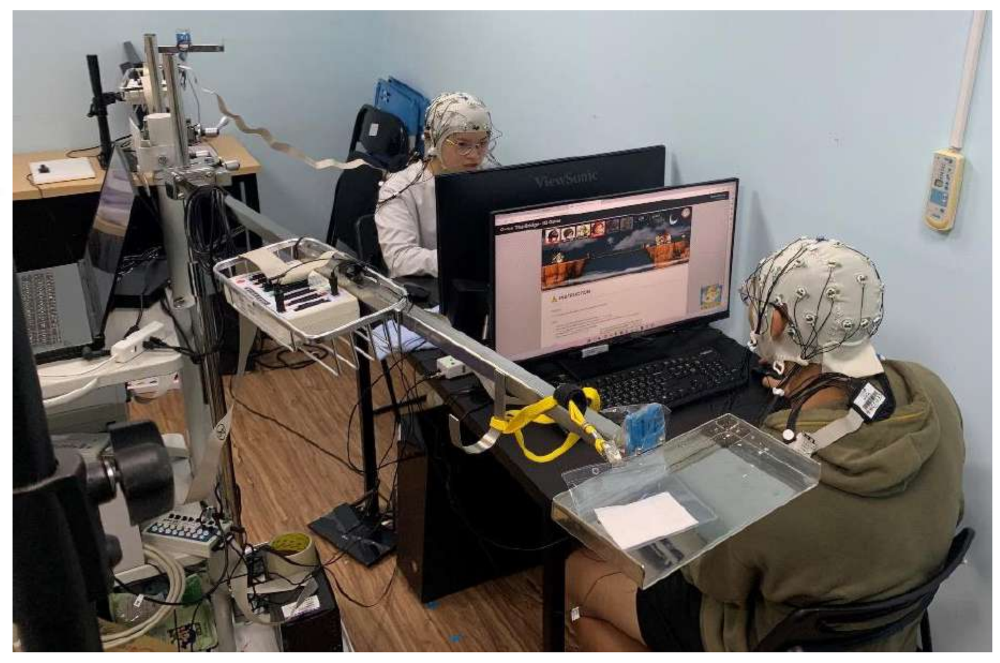


Figure 1. The collected data was sent to the LSL for integration and then into NeuroPype via Lab recorder for immediate feedback; it was then displayed on the Unity screen.

03 Results

Main Finding I: The four indicators were highly consistent across time, with negative correlation at some times. There was a significant increase in the frequency of the sound during the pre- and post-process. The difference between the two was significantly smaller when answering the spatial questions in Question 3 (Change, Maths).

Main Finding II: the mean value of the index was lower for the less difficult questions; 2. The mean value of time and workload for each group showed an extreme positive correlation by the Question Dart.

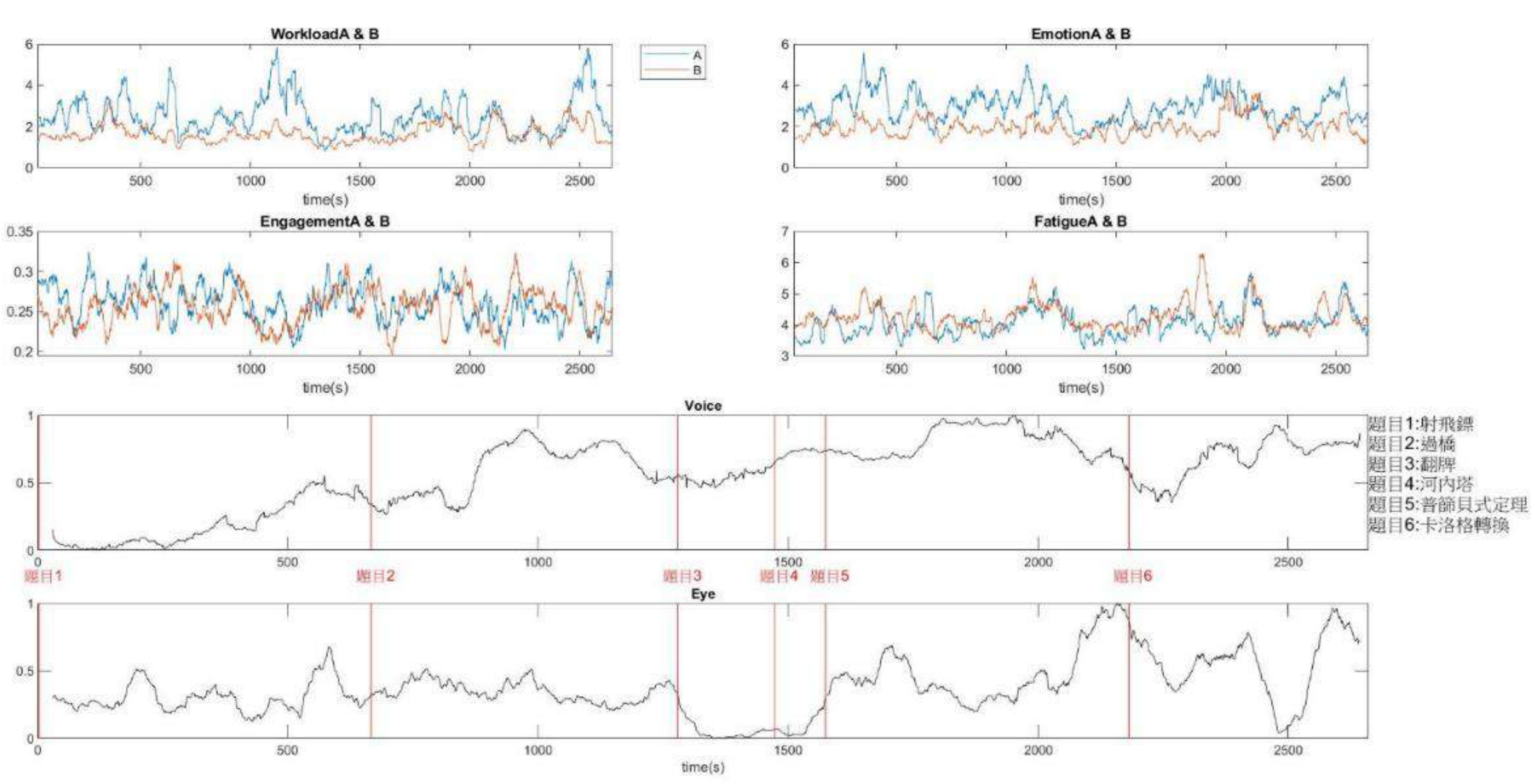


Figure 2. Four indices were calculated based on the brain waves. The frequency of sound was normalized. The eye movements were normalized by calculating the difference between the eye distances of the two subjects through Euclidean distance for easy observation. The four indicators were found to be highly consistent across time, with negative correlation at some times. There was a significant increase in the frequency of the sound during the pre- and post-process. The difference between the two was significantly smaller when answering the spatial questions in Question 3.

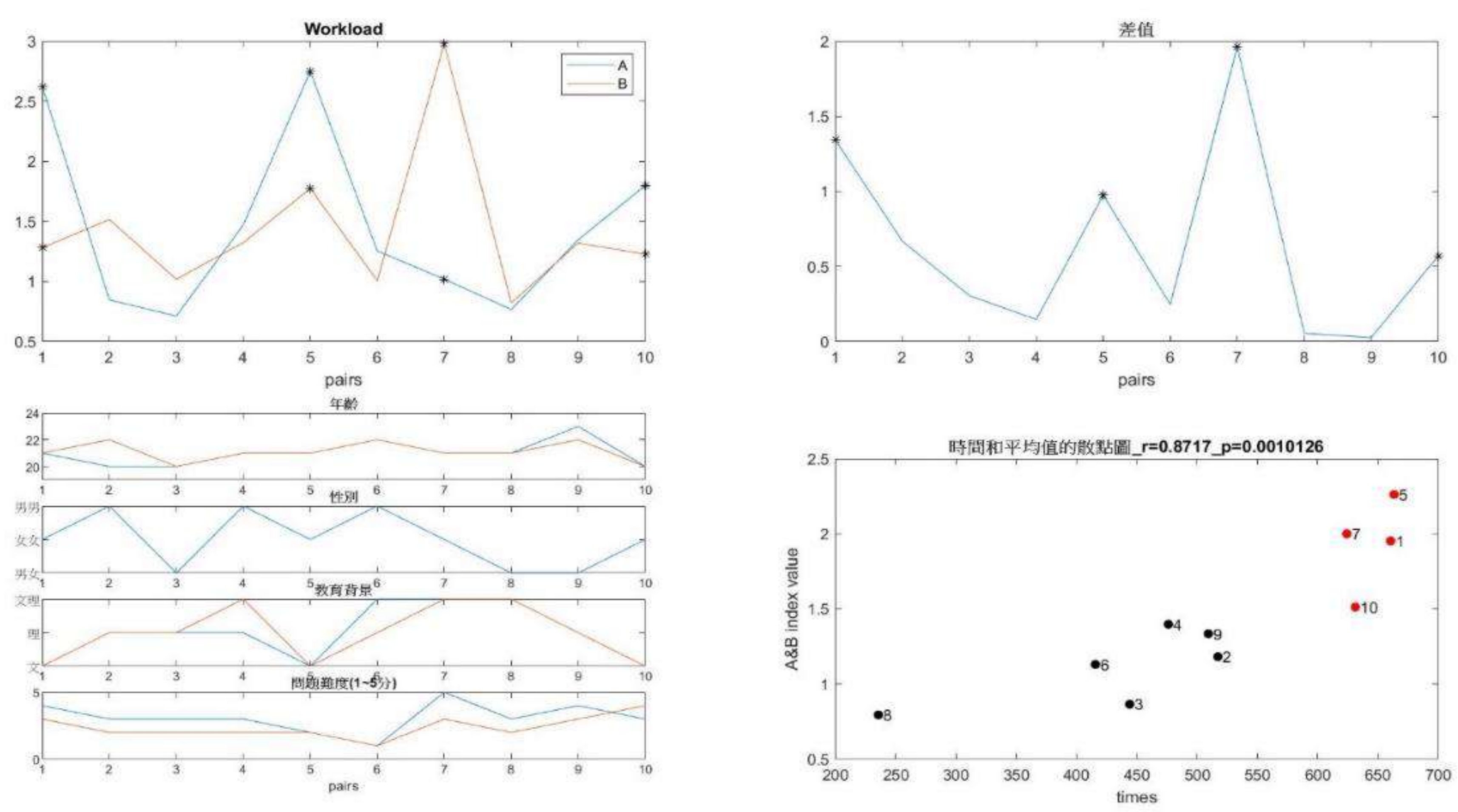
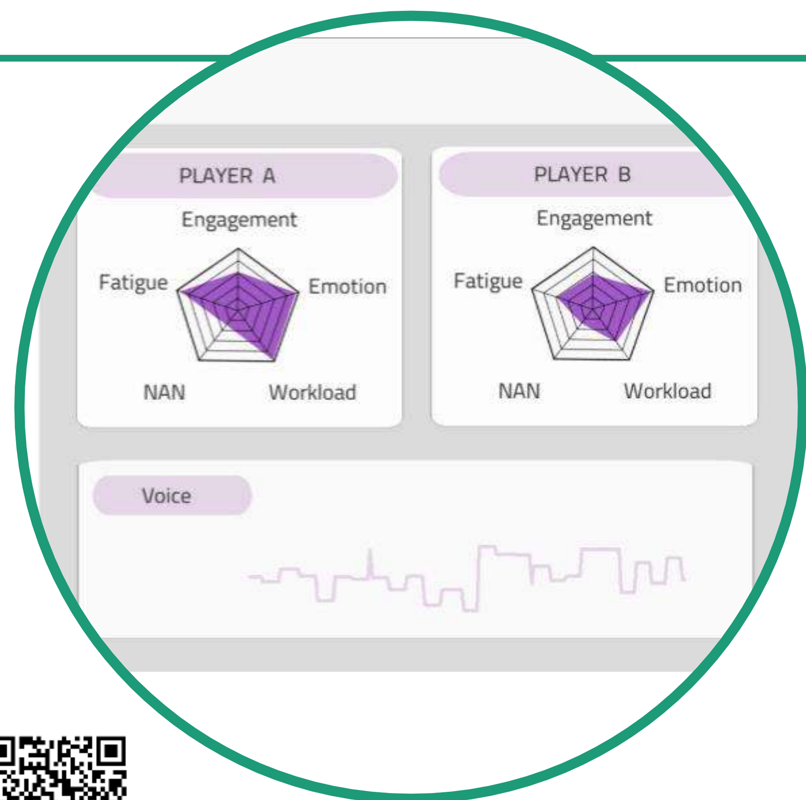


Figure 3. We calculate the indices from the 10 sets of data received. Among them, 6 groups completed all the questions, while 4 groups did not complete them.The average and absolute value of the difference between the workload indicators of two subjects were plotted. A line graph of age, gender, background, and difficulty of each group were also plotted. The average value of time and workload of each group during the Question Dart.

04 Conclusions

During the experiment, we collected online real-time feedback of the subjects' physiological indicators, such as EEG hyperscanning. We analysed the indices combined with the question types, and found that the workload correlation of the subjects was higher when doing Mathematics-related questions, while the index was smaller when doing simple questions. Our future vision is to make an immediate learning feedback, such as a pentagon diagram(Diagram 1), to present the learner's learning process. The above physiological indicators are the best proof that can show the learning effect.



https://youtu.be/iYJVM7zfQBE

05 References

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