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► To cite this version:

Arnaud Prouzeau, Sébastien Rimbert. Toward Enhancing Workspace Awareness Using a Brain-Computer Interface based on Neural Synchrony. 5th International Neuroergonomics Conference, Jul 2024, Bordeaux, France. <hal-04643369>

HAL Id: hal-04643369

<https://hal.science/hal-04643369v1>

Submitted on 10 Jul 2024

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Toward Enhancing Workspace Awareness Using a Brain-Computer Interface based on Neural Synchrony

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This work explores the potential of EEG-based passive Brain-Computer Interfaces (BCIs) to enhance workspace awareness using EEG synchrony indices to track cognitive states in real-time. Using such measures, it would be possible to detect and adjust for misalignments in team members' focus and engagement, potentially preventing communication failures. We envision techniques that provide real-time feedback on team dynamics, enhancing decision-making processes within collaborative tasks. In the future, we plan to run a study to assess the performance and impact of such techniques.

Background

Workspace awareness in a collaborative context is defined as the understanding of what collaborators are doing within a shared workspace (Dourish and Bellotti, 1992). It was broadened by Gutwin and Greenberg (2002), who defined it through the answers to three questions: (i) Who is working in the workspace, (ii) where they are working within it, and (iii) what they are doing. To provide such information, techniques were proposed ranging from shared cursors and radar views (Gutwin, C., & Greenberg, S., 1998) to more complex systems incorporating user head and eye trackers (Newn et al., 2017, Prouzeau et al., 2018). While these techniques are effective for monitoring observable actions, they often overlook the deeper cognitive engagement of collaborators in each other's activities, known as collaborative coupling (Tang et al., 2006). This coupling goes from loose (e.g., collaborators working independently) to close (e.g., collaborators working on the same task), and in many situations, it is inferred by participants. However, dynamic and cognitively demanding environments, breakdowns in collaborative coupling can happen and lead to severe misalignments, such as those contributing to the crash of Air France Flight 447. After the autopilot disengaged, one pilot attempted to make the plane climb, probably to escape the storm, while the other was trying to stabilize the aircraft to identify the failure. This misunderstanding between the crew members was noted in the investigation report (BEA, 2012) as a contributing factor to the misidentification and mismanagement of the situation.

Such contexts underline the potential of passive Brain-Computer Interface (BCI) based on electroencephalographic (EEG) signal to provide real-time insights into team members' cognitive states, potentially averting miscommunication by alerting teams to discrepancies in mental alignment and focus, thereby enhancing collaborative effectiveness. Indeed, several articles have highlighted a neural synchrony index in tasks involving collaboration in ecological settings (Toppi et al., 2016), design and building (Aruon et al., 2024) or musical improvisations between two musicians (Ramirez-Moreno et al., 2023). It would therefore be possible to use this index as an input for a passive-BCI, enabling cooperation to be encouraged via neurofeedback (Schattner et al., 2023), or the design of the support interface to be modified accordingly to assist cooperation.

Methods

In this preliminary design study, we investigated the potential of BCI-based on EEG synchrony to enhance workspace awareness by conducting a comprehensive literature review on the current

applications of EEG synchrony. We complemented this with an analysis of situations where there was a documented breakdown in collaborative coupling, such as communication failures in critical environments. This approach helped us identify critical indicators of EEG synchrony relevant to team dynamics. Based on these insights, we developed hypothetical scenarios to explore how EEG synchrony could provide valuable feedback on team engagement and alignment. This foundational work helped us identify opportunities for the use of EEG synchrony to enhance workspace awareness.

Results

Indicators of EEG Synchrony

By using EEG neuromarker indices that reflect synchrony, it will be possible to create a passive BCI to improve collaboration between users. We propose to investigate synchrony using EEG features such as brain connectivity, modulation amplitude, complexity, and entropy measurements (Clerico et al., 2018). These EEG measurements that are not usually investigated all together will provide more precise modelling of the EEG synchrony, thus providing new leads to improve collaboration.

Opportunity to enhance workspace awareness

Real-time collaborative coupling feedback: With measurements from EEG synchrony, it would be possible to provide participants with real-time feedback on their collaborative coupling. Such feedback can lead to quicker adjustments in team strategies, communication, and roles to enhance overall effectiveness and help in detecting situations where there is a breakdown in coupling. We can display this information in a shared workspace using a dedicated widget or by integrating it into existing workspace awareness techniques. For example, if the focus of users is already visualized in the workspace using colored scrollbars on the side of the screen (Prouzeau et al., 2018), the colors of these scrollbars could represent the level of coupling, with dissimilar colors indicating loose and identical colors indicating close. Additionally, this information could assist users in detecting situations where they are working closely on related tasks, potentially offering opportunities for enhanced collaboration. For instance, if two people are working on the same document in related sections but show loose coupling, the system could provide a viewport showing the other's view, encouraging them to collaborate closely.

A posteriori analysis: Analysed a posteriori, these data can help understanding the dynamics of collaborative efforts. Especially in critical systems, to investigate incidents and determine if a breakdown in collaborative coupling occurred. Furthermore, predictions could be made about how two people will collaborate: whether they are likely to work closely throughout a task or prefer to divide the work. These predictions can then inform system adjustments, allowing interfaces to be tailored to better suit the collaborative styles of the users, enhancing both the efficiency and effectiveness of future collaborative efforts.

Discussion

This position paper introduces a novel perspective on enhancing workspace awareness through EEG-based synchrony indices. We are planning a study to assess how this approach can improve the performance of dyads in problem-solving tasks. Additionally, the study will explore the impact of these techniques on team dynamics, particularly how the presentation of such feedback from one session to another influences collaboration among participants. Finally, it will allow us to discuss the ethical dimensions of this technology, focusing on privacy concerns and the comfort level of participants with receiving and showing direct feedback of their brain activity.

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