A Dual Passive & Reactive-Based SSVEP Brain Computer Interface in the Cockpit

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Introduction

Brain Computer Interfaces (BCI) offer interesting perspectives for neuroergonomics applications to enhance human-machine teaming (Dehais, Lafont, Roy, and Fairclough, 2020). There exist three types of BCIs: active, reactive and passive BCI (Lotte & Roy, 2019, Zander and Kothe, 2011). Active and reactive BCIs allow users to operate an artifact under voluntary control. Reactive BCI (rBCI) discriminates the user's cerebral responses to specific stimuli and translates it into associated commands. Steady States Visual Evoked Potential (SSVEP) is the most popular and efficient approach for rBCI as calibration time is relatively short while classification accuracy is high (Nakanishi et al., 2018). However, flickering stimuli may distract the user's attention from the task at hand and induce ocular fatigue (Ladouce et al., In press). Recently, the NextMind (www.next-mind.com) company has developed a novel type of SSVEP stimuli that is less straining on the eye. Passive BCIs (pBCI) construes the brain activity during a task in order to estimate mental states (e.g., fatigue). The nature of the interactions is then adapted accordingly to overcome cognitive bottlenecks (Zander and Kothe, 2011). One major drawback of pBCI is that the calibration requires the induction of the mental states (e.g., different levels of stress or attention) in a repetitive fashion to train the model. It is difficult to achieve under laboratory settings and more importantly is detrimental to the user-experience. One alternative approach would be to take advantage of SSVEP as frequency tagging stimuli to implement a pBCI. By placing these frequency tags within the background of different regions of interest, one can measure the intensity of the brain response and derive the level of attention allocated to these specific areas.

Aim of the study

The goal of this experiment is to implement a novel concept of neuroadaptive technology, namely a dual BCI and to test it in a challenging and realistic scenario. By "dual", we mean that we intend to combine both "reactive" and "passive" components of the BCI to support direct and implicit interactions for end-users. We used the NextMind SSVEP-based stimuli, headset and classification algorithm to decode pilots' intention to interact with the interface (rBCI), but also to infer their level of attention on a monitoring task and to adapt the interaction accordingly (pBCI).

Figure 1: Left: the participants had to perform the checklists with the reactive BCI (in red, upper part of the screen) while their monitoring performance on the radar screen was assessed with the passive BCI (in blue, lower part of the screen). Right: the dual BCI set up in ISAE-SUPAERO flight simulator.

Methods

We have designed a scenario in which the participants had to perform several checklists (rBCI) and a radar monitoring task (pBCI) along with a traffic pattern exercise The participants had to use the rBCI during:

- takeoff to retract the gear, to retract the flaps, to switch off the lights and to engage the autopilot;
- crosswind to disconnect the autopilot;
- downwind to lower the flaps and to switch on the lights;
- final to lower the landing gear.

Meanwhile, participants should monitor the anti-collision radar. It implies looking frequently at this radar to determine if another plane (pictured by a gray circle) reaches the middle of the screen, indicating a collision. If so, participants should touch the screen to avoid collision. The radar has an NextMind-SSVEP in the background. Thus, frequency-tagging is used to assess the level of attention of the pilot. If this attention is too low and a collision is incoming, the system would infer that the pilot would not touch the screen (e.g. avoid the collision). It would then automatically activate the anti-collision maneuver and trigger an orange visual alert. The visual presentation and stimuli-decoding of the dual BCI is implemented using the NextMind Unity SDK. The level of attention for the pBCI is derived from the "confidence score" (threshold empirically set to 0.2) delivered by the NextMind classification framework. Participants were equipped with the NextMind EEG headset and a portable Tobii Glasses II eye tracking system. The eye tracker and the touch screen interactions are not part of the dual BCI system, but were used for post-hoc analyses 1) to assess the accuracy of the rBCI and measure the reaction time to perform the checklist events and 2) to quantify the accuracy of the pBCI. We used subjective analog scales to assess the levels of mental effort and frustration to perform the checklists (0 = very low, 10 = very high). Four pilots took part in this experiment (ethic committee approval number 2020-334). This work was part of the Neurosynchrone project (NextMind and ISAE-SUPAERO) funded by Agence Innovation Defense.

Preliminary results

Regarding the rBCI, all the participants managed to fly the aircraft and perform the checklists successfully with only a single false positive (i.e. activation of an undesired item) over 40 minutes of recording. The mean reaction time to interact with the items was 2776 ms (SD = 978 ms). The mean reported level of mental effort was 2.3 (SD = 1.9) and frustration was 3.4 (SD= 1.4). Regarding the pBCI, the participants missed a total of 14 potential collisions out of 64, which were compensated by the pBCI system. Besides that, we recorded that the anti-collision system failed to trigger while pilots were looking at it on average 1.75 time per flight (false negative).

Discussion

This is the first demonstration of a dual BCI system using SSVEP for pBCI purposes. The analyzes disclose promising results since the pilots did not report any subjective difficulty in using the system and exhibited relatively short reaction times with the rBCI. We would like to emphasize here that pilots were engaged in a complex and realistic multitasking activity and in a flight simulator (i.e., noisy with muscular activity and electromagnetic contamination). The pBCI provided assistance to the pilots by triggering safety maneuvers with an acceptable rate of false negatives. This hybrid approach provides flexibility since the expertise of the pilot is kept at the center of the design while providing a safety net in case pilots attentional resources are engaged on other aircraft operations. It is an improvement compared to automatically activating anti-collision whenever a collision is coming. In some cases, the pilot could have paid attention to this incoming danger but determined that anti-collision was not necessary. In our scenario, the anti-collision safety was triggered only if the pilots deliberately chose to do it or if he was not paying attention. Future work will focus on collecting more data in simulator and real flight conditions.

References:

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