Neuroergonomic Evaluation of A Genuine Air Traffic Control Alert

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Despite the drop in air traffic due to the COVID-19 pandemic, pre-pandemic high levels of traffic and their correlative issues will be reached soon. In 2019, 62333 incidents caused by Air Traffic Management were reported in Europe (EUROCONTROL, 2020). The analyses of these events stress the importance of visual attention related issues as a main causal factor (Jones and Endsley, 1996; Shorrock, 2007). Different "warning" and "alert" notifications have been developed to overcome the "inattentional blindness" phenomenon while keeping the human operator in the loop. For instance, the Short Term Conflict Alert (STCA) consists of a small blinking red" ALRT" tag, that relies on increased salience, and hence bottom-up processes, to capture attention. However, some experiments disclosed that STCA could remain undetected especially under high load settings (Imbert et al., 2014; Saint Lot et al., 2020), showing that there is a need to design new solutions to assist air traffic controllers in detecting unexpected events. Saint Lot et al. (2020) successfully tested a red ambient flash that masks the entire screen for 300 ms with a 15% opacity visual red flash. Alternatively, auditory or vibrotactile based stimuli could be used since these modalities are less solicited than vision in air traffic control.

Aim of the study

The goal of this experiment was to assess the efficiency of the current French STCA alert and three other types of alerts to mitigate inattentional blindness. Hypotheses were that the acknowledgment rate of alerts would decrease with the level of workload and time on task and that the classical STCA alert would yield more missed alerts than the other alerts. We collected classical behavioral metrics as well electrophysiological ones to evaluate these designs and investigate the neural correlates of inattentional blindness under ecological settings. We expected that the less efficient alarms, such as the STCA, would be associated with a low P300 amplitude, showing reduced sensory processing (Polich, 2007), and a high power in the α-band prior to missed alarms that would reflect a cortical inhibition leading to decreased attention (Mathewson et al., 2009).

Method

Twenty-nine French student air traffic controllers (19 men, 10 women. Age: M = 23.21, SD = 3.60) with prior radar training experience performed a low-fidelity ATC simulation in a high-fidelity environment. Participants were equipped with a Brainvision LiveAmp EEG sampling at 500Hz, with 32 Easycap active electrodes. Three levels of workload (low, medium, high) were simulated during a 24-minute dual task. The main task was the ATC simulation. As a second task, 108 STCA alerts of four kinds (the classical STCA, and three multimodal countermeasures: a red ambient flash on the screen, an auditory sinusoidal signal at 500Hz, and a square vibrotactile signal at 250Hz in the seat of the chair) were triggered, which participants had nine seconds to acknowledge. All alert countermeasures lasted 250ms, and prior to the simulation, participants had to adjust their level (i.e. amplitude of the sound and vibration, and opacity of the flash) so that they provoked the same perceived urgency.

Acknowledgment rate of alarms and response time were acquired. ERPs were extracted from the EEG signal over the mid-line electrodes. Workload was assessed by the NASA-TLX questionnaire (Hart & Staveland, 1988). Other analyses such as computation of the EEG task load index from Gevins & Smith (2003) or engagement index from Freeman & al. (1999) will also be performed later.

Results

Error counts were modeled by a Poisson regression and showed that there were more missed alarms in high workload (101) than in medium (46, $p < .001$) and in low workload (23, $p < .001$). This confirms our first hypothesis. Most missed alerts (112) were of STCA type, significantly more than vibrotactile (22, $p < .001$), auditory (20, $p < .001$) or visual ambient (16, $p < .001$) alerts, confirming our second hypothesis. A visual inspection of the time course of the EEG signal at Pz (see Figure 1.) showed that the STCA alarm did not clearly generate any of the classical ERPs (e.g. N100, P300,...). Conversely, the countermeasures elicited distinct (albeit delayed) P300.

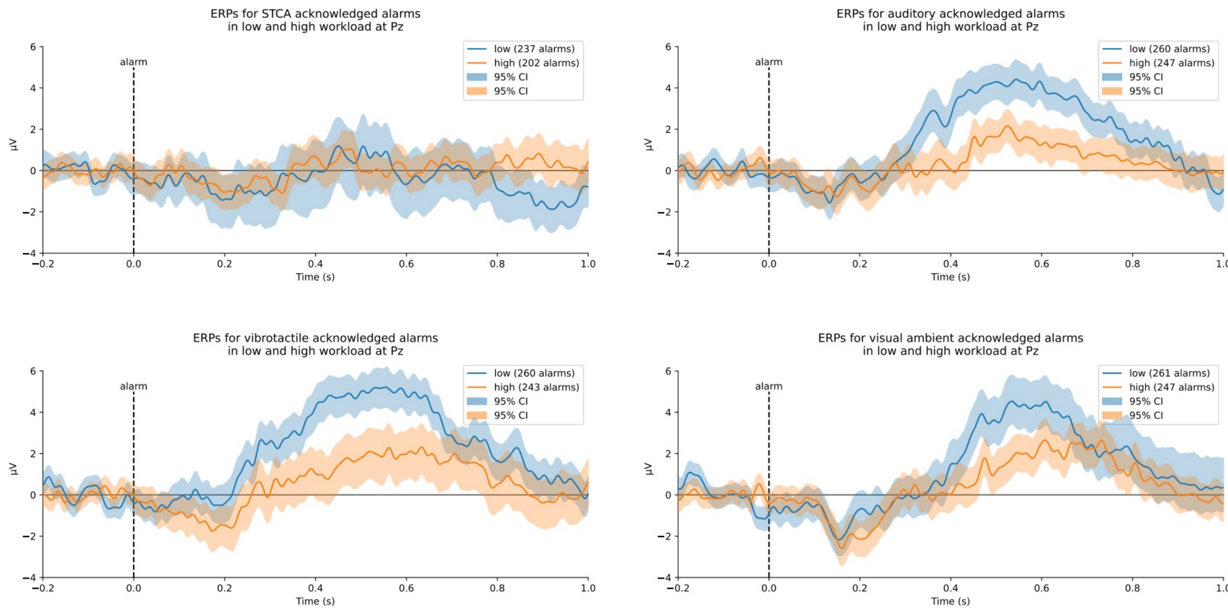

Figure 1: ERPs at Pz for the four alerts. Only the STCA did not generate a distinct P300, showing a lack of attentional capture.

Discussion

The absence of ERPs for the STCA, even though all alarms were located within peripheral vision that is sensitive to color changes and movement, shows the lack of effective bottom-up attentional capture by this alarm. On the contrary, the P300 generated by the countermeasures is evidence of attentional processing. These results are consistent with impaired top-down attentional control leading to missed alarms, which, once restored thanks to bottom-up attentional capture, allows to search for and acknowledge most alarms. Taken together, these results support the hypothesis of inattentional blindness in air traffic control. The effectiveness of the countermeasures advocate for neuroadaptive countermeasures (Dehais et al., 2020) based on the cognitive state of the user, which could help to achieve a balance between effective attentional capture and primary task performance (Imbert et al., 2014). However, this experiment did not allow to determine which countermeasure is most robust to inattentional blindness.

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