Stress variations and auditory omissions: a pilot study

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Introduction

The use of auditory alerts is widespread in peripheral monitoring activities, where the attentional focus of the operator can be diverted from the monitored system toward a secondary task (Hermann et al., 2011). In such activities, an attentional cross-modal phenomenon can arise, leading to omit critical auditory alerts when the operator presents an over-engagement toward a visual task (Dehais et al., 2019).

The phenomenon of auditory omissions has been widely studied in aeronautics under the term "inattentional deafness" (ID) (Giraudet, 2015). In this context, studies evidenced the existence of an attentional bottleneck impacting both early and late processing of auditory stimulations (Durantin et al., 2017). These studies were mostly conducted using MEG, EEG and fMRI to explore its neuronal correlates (Dehais et al., 2020), and secondary tasks employed to induce ID (e.g., during a landing task) were usually specific to the flying context.

Stress is the reaction of an individual towards environmental pressure, on three dimensions including neurophysiological, behavioral, and subjective modulations. Its effects can induce ID through a deleterious impact on regions supporting attentional abilities and executive functions (Dehais et al., 2019), or through an attentional bias toward the stressors (Eysenck et al., 2007).

This pilot study had two objectives:

- Explore the occurrence of ID (behaviorally defined as the occurence of omissions) during a secondary task imitating those which could take place in large-public contexts (e.g., autonomous driving), and its neurophysiological correlates.
- Study the suitability of subtle biofeedback stress reduction and examine whether it affects the occurrence of ID (Béquet, Hidalgo-Muñoz & Jallais, 2020).

Methods

Twenty-nine participants were included, aged from 19 to 60 years (M=34.1, SD=10.9).
The monitoring task consisted of responding "as fast as possible" to auditory alerts by pressing a footswitch. There were 11 alerts, separated by 40 +/- 15 seconds in four blocks of 8 min, randomized by an interval of presentation to avoid anticipatory effects and periodical signal contribution (e.g., Mayer waves) in functional Near InfraRed Spectroscopy (fNIRS) acquisition. The secondary task consisted in the memorization and restitution of green light patterns displayed on an 8*8 button touchpad similarly to the "Simon air" game (figure 1). The restitution immediately followed the memorization step. Two levels of difficulty were implemented using pattern length: Easy (from 1 to 7 buttons), and difficult (from 7 buttons, without maximum). Different levels of stress were induced using gauges on both sides of the touchpad: performance evaluation, social and temporal pressure. The biofeedback device emitted slight vibrations throughout the condition, using 2 actuators placed on the inner-wrist (Costa et al., 2016). Inter-vibration intervals were set to be larger than the actual heartbeat intervals by a factor of 1.5.

Several questionnaires collected subjective feelings (using the Geneva Emotional Wheel and the NASA-TLX) and personality traits (using the Big-Five Inventory). We measured physiological (electrocardiogram, respiration, electrodermal activity) and neurological (using fNIRS) data throughout the experiment.

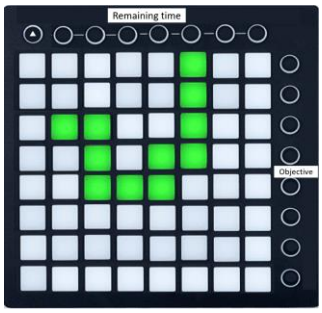

Figure 1. Touchpad hardware employed for the secondary task and example of a pattern

There were 4 randomized blocks: (1) Control condition with an easy secondary task, (2) Difficult secondary task, (3) Difficult-Stressful secondary task, (4) Difficult-Stressful secondary task and Biofeedback. Each block was 8-minute long and contained both audio and visual tasks.

Results

Behavioral and subjective data

Preliminary results illustrate an impact of stressful blocks on the occurrence of ID (2nd block: 2 omissions versus 3rd and 4th block: 10 and 11, respectively; X^2=5.15, p<.05). Exploratory analysis using Welch's t-test shows that the eight participants experiencing ID are significantly older (M=42.2 years, SD=11.36) than the others (M=31 years, SD=9.21) in the third block (t= -2.49, p<.05, d= -1.14). Furthermore, participants report a higher level of stress felt during the third block (M=2.138, SD=.882 in block 2; M=2.533, SD=.813 in block 3; t=-2.934, p<.005, d= - 0.545). There is a moderated impact of the biofeedback on stress level only when extraversion and mental flexibility are included as covariables (M=2.316, SD=.931 in block 4; F=4.933, p<.05, η_2=.022).

Neuro-physiological data

Physiological data was processed using Matlab. Extracted parameters were normalized using the first block as baseline. We found an effect of stress on heart rate (M=.007, SD=.069 in block 2; M=.039, SD=.081 in block 3 ; Z=2.650, p<.01, r=-.368), on breathing rate (M=-.007, SD=.061 in block 2; M=.028, SD=.073 in block 3 ; Z=2.242, p<.05, r=-.338), and on the number of electrodermal responses (M=-.276, SD=.384 in block 2; M=-.015, SD=.523 in block 3; t=-2.863, p<.01, d=-.625).

Regarding fNIRS, a processing pipeline adapted from (Laurent et al., 2021) was employed. We looked at temporal areas for participants with omissions. There is a significant reduction of oxyhemoglobin concentration change for omissions compared to perceptions (t=-2.238, p<.05, d=-.598). Note that the averaging of omissions signals was conducted on a fewer number of trials than perceptions (21 vs 133).

Conclusions and perspectives

The primary objective was to check whether ID could happen in peripheral monitoring contexts accessible to a large public. While only 3% of alerts were omitted in stressful conditions, results show that older people seem more prone to ID. Preliminary results illustrate that ID can arise within simple tasks and that considering age is relevant. In line with previous works, the occurrence of ID also seems linked to stress,

as illustrated by the subjective and physiological results. Moreover, the first fNIRS result regarding participants who failed to notice the alert shows a reduced temporal activation for the omission. This suggests the influence of an attentional bottleneck at an early stage of auditory processing in our experiment. Further analysis on other regions involved in this mechanism and their connectivity to temporal regions will be conducted. Regarding biofeedback, inter-individual characteristics seem to be relevant when studying its efficiency. However, there was no impact on ID nor physiological data.

Additional research investigating the occurrence of ID in a wide-public context would be desirable to ensure the safety of non-expert operators. Specifically, level 3 of autonomous driving presents an interesting application: operators will have to perform peripheral monitoring of the vehicle, being authorized to achieve potentially over-engaging secondary tasks (SAE, 2018).

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