The Human-Systems Interaction groups at ONERA and ISAE-SUPAERO received funding for a PhD project in Neuroscience/Neuroergonomics titled:

Reducing the negative impact of stress on decision making: combined effects of cerebral and vagal non invasive stimulation

General background

Stress can be defined as "a condition or feeling experienced when a person perceives that demands exceed the personal and social resources the individual is able to mobilize" (American Institute of Stress, 2020). Stress generates in individuals responses similar to those experienced during emergency situations, such as unsatisfactory solution seeking (Edland & Svenson, 1993), deficitary evaluation of available alternatives (Hogarth & Makridakis, 1981), using extremely simplified strategies (Van Bruggen et al., 1998) and rejecting evidence that do not support the current action plan (Wright, 1974). The negative effects of stress on decision making mechanisms in the context of complex systems' control have been largely studied (e.g. Hancock and Desmond, 2001; Martinussen & Hunter, 2010; Ursin & Eriksen, 2004 ; Starcke and Brand 2012). Research using a flight simulator, for instance, showed that stressful situations, such as the appearance of conflict during piloting (e.g. pilot/copilot conflict, pilot/automatic pilot conflict, etc.), especially under uncertainty conditions, can generate a behavior similar to a disexecutive syndrome (Dehais et al., 2010), leading pilots to take irrational decisions and to persist in their incorrect choices (Reynal et al., 2017).

Perseverating in an incorrect behavior can also result from an attentional focus on specific information, while ignoring environmental stimuli that signal us that the current behavior is incorrect. Such "attentional tunneling" has been operationalized in the context of human factors by Wickens (Wickens, 2005 ; Thomas et Wickens, 2004). From a cognitive point of view, such attentional focus induces the so-called "confirmation bias", which results in the active research of information supporting a proposed hypothesis or decision, and the "plan continuation bias", that is behavioral perseveration. Stress and temporal pressure, both present in emergency situations, can reduce the number of environmental information actively researched and treated by operators (Ozel 2001), and enhance attentional tunneling (Staal, 2004 ; Dehais, 2012). The results of this altered behavior, in an operational context, could produce dangerous, and sometimes fatal, consequences.

Four factors seem to characterize a stressful situation and negatively affect the quality of decision-making: informational overload, temporal pressure, decisional complexity and uncertainty (for a review, see Phillips-Wren & Adya, 2020).

Objectives

While the understanding of the negative effects of stress on cognition is a necessary step to the research of possible solutions, the present PhD project aims to go further and seeks to *evaluate possible solutions to reduce the latter under ecological conditions.*

To this aim, the stressful situation will be induced during a flight simulation, by using ambiguous cues that generate uncertainty, in a context that requires a quick decision (e.g. landing phase, engine failure, etc.). Two types of non-invasive stimulation will be used in an independent and combined fashion to

obtain cumulative positive effects on the cognitive functions negatively impacted by stress (Zao et al., 2022 ; Sun et al., 2021).

Specifically, non-invasive cerebral electrical stimulation (tRNS - transcranial Random Noise Stimulation), will be applied to reduce the negative effects of stress, particularly on attentional control (Corbetta et Shulman, 2002 ; Hanna -Pladdy, 2007 ; Mayr , 2006 ; Milham , 2001). tRNS will be used to stimulate the brain regions involved in visual attention orienting (Corbetta et Shulman, 2002), inhibition and information selection (Hanna -Pladdy, 2007 ; Mayr , 2006 ; Milham , 2001), depending on the task.

Trans-auricular vagal nerve stimulation (tAVNS), which induces an excitation of the parasympathetic system, will be used to reduce globally the level of stress in participants (Badran et al., 2018).

Expected results are a reduction in the level of stress perceived by participants (measured through subjective evaluation scales, electrocardiogram and the level of salivary cortisol), an increase in performance, and better attentional control (detected through eye movements). Positive cumulative effects of the combined use of the two stimulation techniques on these variables are expected.

These innovative studies aim at *using (neuro)modulation techniques to reduce the negative effects of stress in ecological conditions*. From these results, future studies will be able to test reduction in pilots' stress levels in real time, thanks to trans-auricular vagal stimulation, and improvement in stress management in the middle/long term, thanks to repeated non-invasive electrical stimulation sessions.

Supervision, research center and time schedule

The PhD project will be carried out at ONERA (Salon de Provence, France), under the supervision of the co-supervisor Dr. Stefania Ficarella and with regular exchanges with the PhD supervisor Dr. Sébastien Scannella and the ISAE-SUPAERO group in Toulouse (France).

The PhD project will take place over three years, from the last trimester of 2023 and the last trimester of 2026 (starting date to be defined).

The PhD candidate will produce a synthesis of the relevant scientific literature on the negative effects of stress on attentional control, plan the experimental protocols, collect and analyze psychophysiological data and participate in the redaction of associated scientific articles.

Candidate's profile

- Master's Degree in Cognitive Sciences or similar disciplines, engineering school
- A familiarization with Matlab and/or Python is required
- Experience with non-invasive brain stimulation is appreciated but not required
- Motivation, scientific rigor and ability to collaborate

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