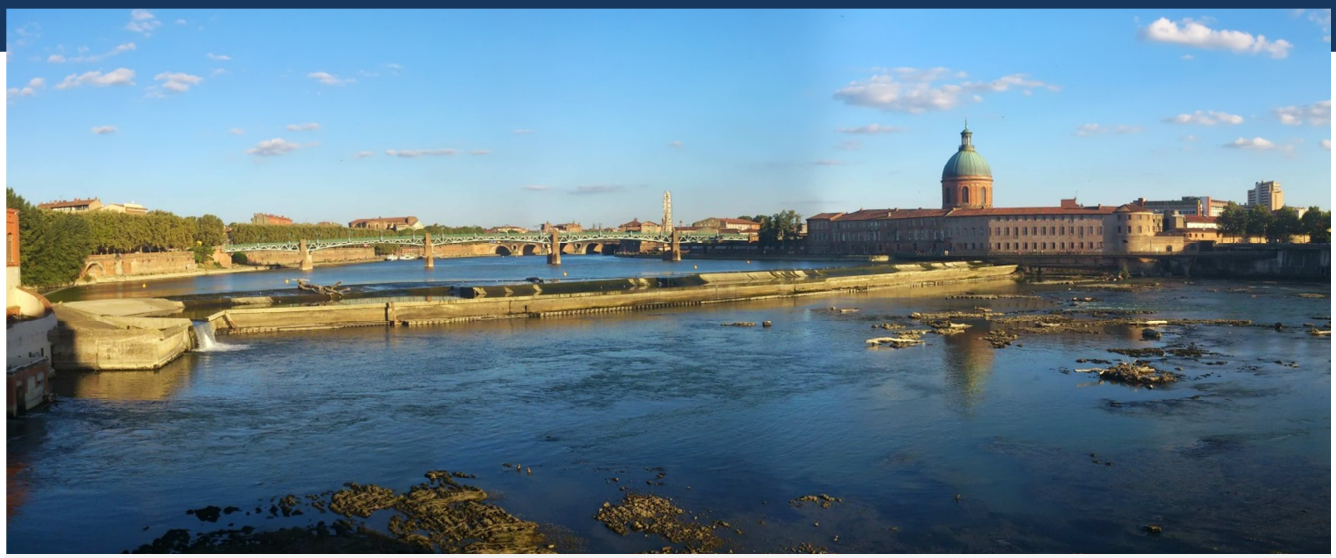

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Flight simulator and fNIRS : study of relation between acute stress and cognitive workload

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Content

In aviation, knowing the internal state of pilots is desirable to prevent and detect abnormal situations such as an excessive cognitive workload (CW) or acute stress, both known to impact human performance 1. Detecting these states becomes crucial with the possible emergence of Single Pilot Operations (SPO), during which tasks will be largely supported by a single pilot and the aircraft systems. The mental constructs of CW and acute stress have been extensively studied in the human factor literature, but the analysis of their respective impact in the same ecological situations remains poorly studied. In the current study, twenty-one private pilots from the French Civil Aviation University were recruited. They all performed two realistic flight simulator scenarios with the same difficult level and duration (around 35 minutes each). The CW was manipulated with the difficulty of a secondary task (low CW vs high CW; for details, see [2]) and the level of stress was manipulated by means of a social stressor (low arousal vs high arousal). We examined brain hemodynamic activity via functional near infrared spectroscopy (fNIRS) with a portable NIRS system (NIRSport, NIRx Medical Technologies, NY, USA). We recorded 14 fNIRS channels that were subdivided to create four regions-of-interest: left prefrontal and parietal cortex; right prefrontal and parietal cortex. Analyzes were focused on oxy-hemoglobin (Oxy-Hb) concentration changes. We found a main effect of CW ($p = .01$, $\eta p^2 = .31$) with a higher Oxy-Hb level under high CW condition vs low CW. This effect of cognitive workload was significant particularly in the right prefrontal cortex (CW x laterality interaction, $p = .01$, $\eta p^2 = .21$). An interaction between CW and acute stress level was also found ($p = .04$, $\eta p^2 = .20$). Post-hoc analysis showed that the increase in Oxy-Hb concentration between high CW and low CW was significant only under high arousal.
In accordance with previous research [3,4,5], our results confirmed that an augmentation in CW leads to an increase in OxyHb concentration. However, the lateralization of this effect to the right prefrontal cortex was a little unanticipated. Usually, left prefrontal cortex is the region where the maximum Oxy-Hb concentration increase was found [5] and manipulation of arousal involves the right hemisphere [6], no such result was found here. The moderate effect of the high arousal conditions tends to indicate that our stress manipulation was relatively weak [2]. However, our results emphasized that the combination of high mental workload and acute stress (high arousal condition) was the one that triggered the higher OxyHb concentration. This result supports the idea that these two constructs might interact and could promote a recruitment of further resources at the expense of unsuitable physiological cost, as proposed by the cognitive-energetical framework [7].
To conclude, fNIRS can accurately assess CW fluctuation and the fusion with other measures could give some complementary information on internal state of the pilot. It has been shown to be an effective tool in cognitive neuroscience and has some interesting operational characteristics: non-invasive, portable, silent, movement tolerant, fast set-up [8].

Keywords : Eye tracking, EEG, fNIRS, Other measurement methods, Brain computer Interfaces