Chapter 41

Assessing Working Memory Load in Real Flight Condition With Wireless fNIRS

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INTRODUCTION AND AIMS

Many studies have emphasized that pilots' working memory (WM) is highly taxed when following air traffic control (ATC) instructions.[1] Several stressors such as message complexity may negatively impact pilots' ability to execute ATC clearances and jeopardize flight safety. To monitor such cognitive limitation, we adopted a neuroergonomics approach to measure neural correlates of pilots' WM performance in real flight conditions.

METHODS

Eleven visual flight rule (VFR) pilots participated in the experiment in the Higher Institute of Aeronautics and Space (ISAE-SUPAERO) DR400 light aircraft during an actual flight at 2500 ft altitude. We used the four-optode/12 channel mini-functional near-infrared spectroscopy (fNIRS) wireless portable device to record the pilots' hemodynamics of the prefrontal cortex.[2] Similar to Gateau et al. (2015),[3] pilots heard prerecorded ATC instructions and were instructed to read them back while flying the aircraft and maintaining altitude and heading. Two levels of difficulty were defined. In the low WM load, only one major digit per trial was used to set each flight parameter (eg,: 17 for "speed 170, heading 170, altitude 1700, vertical speed +1700"). In the high WM load, each flight parameter value was different from the previous one (eg,: "speed 179, heading 245, altitude 5800, vertical speed −1500"). The task consisted of 10 randomized repetitions of each difficulty for a total of 20 trials. Cognitive Optical Brain Imaging (COBI) Studio was used to collect raw fNIRS data that were moving average convergence/divergence (MACD) filtered.[1] The experiment was approved by the European Aviation Safety Agency (EASA60049235) and supported by the AXA Research Fund.

RESULTS

The participants committed on average 8.73 errors [standard deviation (SD) = 2.10] errors during the entire experiment, all occurring during the high-load trials. The analysis of variance (ANOVA) over the fNIRS data revealed a main effect of the oxygenation ($F(1, 10) = 9.39$; $P = .01$; partial $\eta^2 = 0.48$) with higher oxyhemoglobin ($\Delta[HbO_2]$) than deoxyhemoglobin ($\Delta[HHb]$) and a main effect of the load [$F(1,10) = 6.0$; $P = .03$; partial $\eta^2 = 0.37$] corresponding to higher peak response within the high-load condition. In addition, a significant interaction effect between load and oxygenation was found [$F(1,10) = 16.4$; $P < .01$; partial $\eta^2 = 0.62$] showing that the load effect was only present for $\Delta[HbO_2]$ ($P < .001$) (Fig. 41.1).

CONCLUSION

This study demonstrates the efficiency of fNIRS to monitor pilot's WM abilities under real flight settings and paves the way to the implementation of fNIRS-based brain–computer interface in the cockpit.

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FIGURE 41.1 Left: DR400 light aircraft—Right: Pilot, left-seated equipped with the mini-fNIRS; the safety pilot is right-seated.

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