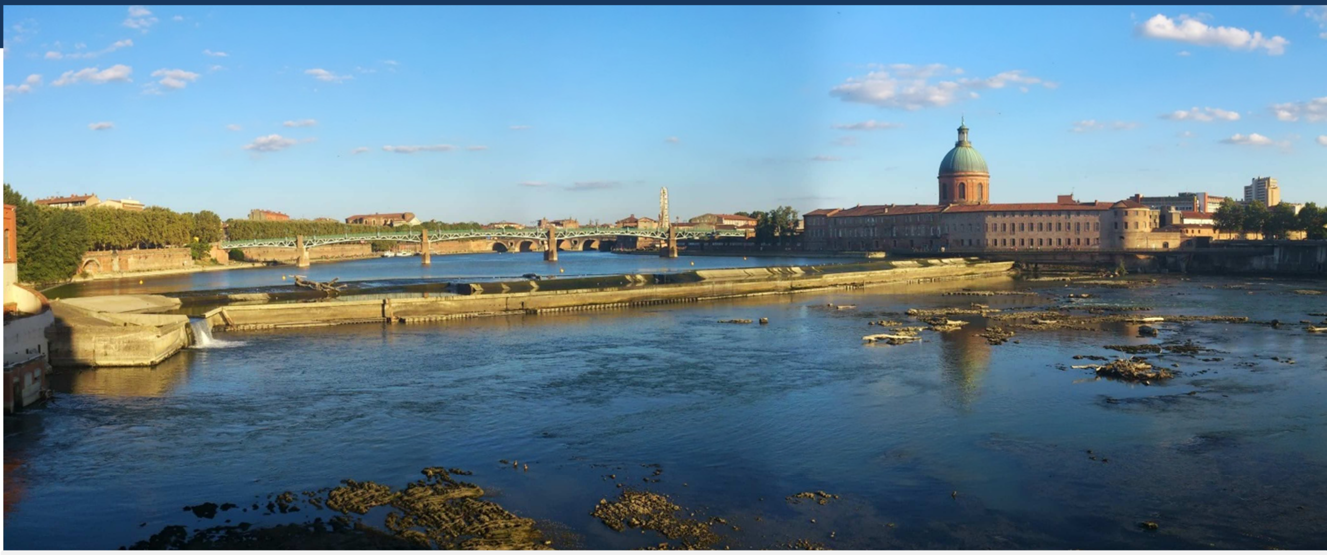

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Effects of visuo-spatial working memory load on auditory attention: behavioural and cortical evidence

DULEME, Méyi (EuroMov Digital Health in Motion, Univ Montpellier, IMT Mines Ales, Montpellier, France); BOROT, Lénaic (EuroMov Digital Health in Motion, Univ Montpellier, IMT Mines Ales, Montpellier, France); BELDA, Guilhem (Semaxone, EuroMov, Montpellier, France); Dr VERGOTTE, Grégoire (Université de Toulouse, Toulouse, France); Prof. DRAY, Gérard (EuroMov Digital Health in Motion, Univ Montpellier, IMT Mines Ales, Alès, France); Prof. PERREY, Stéphane (EuroMov Digital Health in Motion, Univ Montpellier, IMT Mines Ales, Montpellier, France)

Content

Working memory (WM) plays an important role in pilots since they have to continuously integrate and dynamically update information within a rapidly changing environment. WM is essential for overcoming response conflict and for optimal selective attention performance. Yet, WM is a capacity-limited system and increasing the demands on WM reduces the ability to ignore irrelevant stimuli and can led decreased performance in dual –tasking. In the present study we used an experimental approach aiming at providing evidence for the sensitivity of the functional near infrared spectroscopy (fNIRS) in providing measures of brain activity within the prefrontal cortex (PFC), with regard to WM-specific task demands combined to an additional different secondary task.

Sixteen healthy volunteers (mean age ± SD, 24 ± 4 years, 10 females) performed a dual-task paradigm after a learning phase for allowing the normalization of participants' performance and the suppression of strategy-related behavioural variability. The primary WM task was a visuo-spatial n-back task at three difficulty levels (1-back, 2-back and 3-back). A blue square was consecutively and pseudo-randomly displayed in a grid in one out of nine possible locations every 1,750 ms. Participants had to report when the current square position matched a previous one. The lag between the sample and the presently displayed stimulus depended on the level of difficulty. The secondary task consisted of auditory stimuli detection and the participants had to detect a 44.1 kHz sound randomly presented throughout the conditions. Participants had to fill a NASA-TLX questionnaire and a STAI-S short-form questionnaire, to assess mental workload and anxiety state, respectively, related to the n-back conditions. Hemodynamic changes (concentration of oxygenated and deoxygenated -HHb- haemoglobin) were recorded at a sampling rate of 10Hz from a fNIRS system (Octamon, Artinis Medical Systems, The Netherlands) optimized for PFC measurements. The unit consisted of a headband with 8 light emitters and two light detectors, with an interoptode distance of 3.5 cm.

At the behavioural level, signal-detection analysis showed a lesser d' sensitivity for 3-back compared to 1-back and 2-back. Reaction times (RTs) were slower for 3-back compared to 1-back and 2-back. Behavioural efficacy combining d' and RTs for the 3-back was significantly lower than 2-back and 1-back conditions ($P<0.05$), as well as for 2-back compared to 1-back. Sensitivity d' for the auditory task was lower for 3-back than 1-back ($P=0.051$), and higher ($P=0.016$) for test phase relative to learning phase. At the subjective level, we observed a significant progressive increase in the score obtained for the NASA-TLX according the n-back conditions; no changes were observed in the anxiety state. Finally, greater changes in left and right PFC (i.e., increased HHb) were observed for 3-back compared to 1-back and 2-back ($P<0.05$). Taken together, fNIRS might be sensitive enough to assess hemodynamic responses (restricted here to PFC) directly related to cognitive processes elicited by a visuo-spatial WM task combined to an auditory secondary task. Surprisingly, this study showed that the magnitude of HHb signal was the cortical manifestation of cognitive performance limitation in the face of excessive WM load.

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