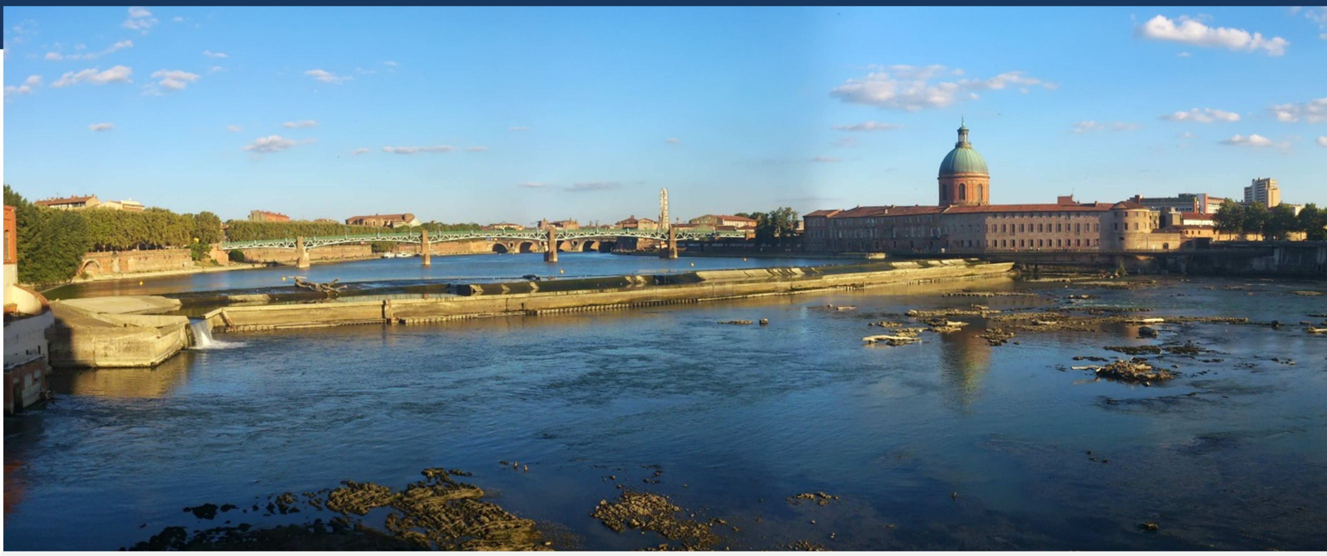

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Exploration of cognitive strategies used on egocentric perspective-taking : an eye-tracking study on 2 different experimental settings : controlled laboratory conditions and simulated-microgravity conditions

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Content

In recent years, eye-tracking is widely used in neuroergonomics and human factors research to explore visual screening and cognitive strategies during complex visuospatial tasks. More especially, aircraft, aerial vehicles, and space navigation require reliable spatial abilities that rely on a frame of reference, i.e. a perspective an operator chooses to describe a location in space or to perform an action. This can be done by using an allocentric or object-centered reference frame, when the object itself or its features orients an operator in space, according to an egocentric frame of reference that exploits the operator's' own perspective, and generally involves a body-axis rotation, or according to a third person that requires an operator to adopt another persons' perspective. Reference frames and thus orientations in space, either real or mental, result from multisensory integration of visual, proprioceptive and vestibular information.
Loss of environmental landmarks, like ISS contexts can have consequences on crewmembers' collaboration.
In microgravity conditions, simulated during parabolic flights, vestibular and proprioceptive inputs are affected what would explain decreased performance when egocentric mental rotations are performed (Grabherr et al., 2007), while little is known when microgravity conditions are simulated in the ground-based dry immersion model that simulates lack of support, mechanical and axial unloading as well as physical inactivity (Tomilovskaya et al., 2019).
To investigate navigation-relevant spatial cognition skills, we proposed a perspective-taking task based on a 2D scene representing the inside of a spacecraft in the background and a floating 4x4 shelf containing several objects. On each trial an avatar popped up behind the shelf and gave an instruction to the participant, i.e. to move one of the objects from one compartment of the shelf to another (up/down/left/right) according to the avatar's point of view. Response times (RT) and errors were recorded to test the involvement of (1) visual information, i.e. the avatar was in a vertical position and the shelf was tilted (-45/+45°),(2) vestibular and proprioceptive information, i.e. the avatar was tilted (-45/+45°) requiring the participant to mentally adjust to the avatar's perspective floating in an unnatural position and (3) both information when the avatar and the shelf were tilted in same or opposite directions. A 45cm black tube was fixed to the computer screen to suppress any external visual cues.
This task was proposed in two experimental settings: 19 participants (mean age = 23,74; 9 males) performed the task in controlled laboratory conditions, and 18 participants (mean age = 33,4; all males) performed the task in DI simulated microgravity conditions. In all participants eye movements were recorded using the SMI 2.0 to analyze cumulative fixation time by AOIs.
Preliminary results, collected in controlled laboratory conditions, showed that mean RTs vary between conditions ($p < .001$) with higher RT in the "shelf-tilt" and "avatar-tilt" conditions compared to the control "no tilt" condition ($p < .01$). Error rates are significantly higher in the avatar-tilt condition ($p <.001$) but not in the shelf-tilt condition ($p=0.062$), compared to the control conditions.
For eye-movements, average cumulative time of fixations of the different AOIs differed between conditions ($p < .001$). In conditions involving an avatar-tilt, and thus an egocentric perspective,

participants spent more time on target AOIs, presumably as the result of higher cognitive load. Further, time spent looking at the right object and the right target was correlated with task success.
This study may allow us to learn more about cognitive strategies used by astronauts to communicate in unusual situations such as microgravity.

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