A neural marker of topographical disorientation during realistic spatial navigation tasks

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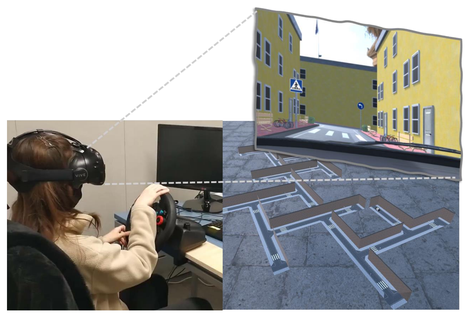
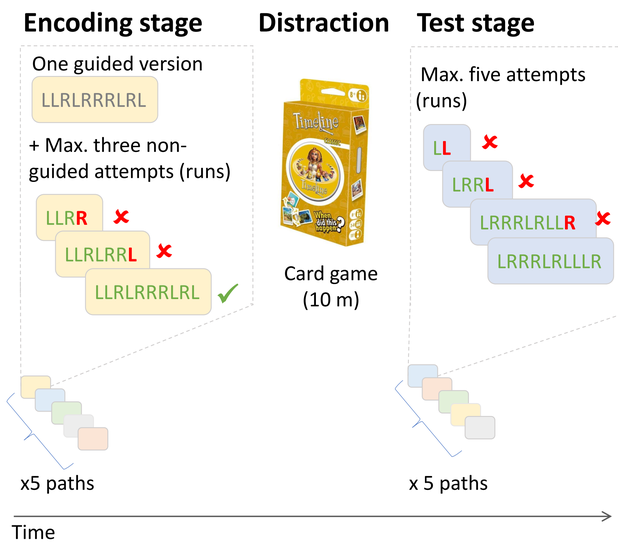
Virtual navigation task



We generated paths in a virtual city composed of randomly selected sequences of left-right turns. Each path sequence was different and was characterized by unique visual features (wall colour, urban furniture style, skybox,…). We used a VR maze generator designed by S. Ávila (2023).



We recorded EEG (64e montage) + reaction time and accuracy for each turn in both stages.

Topographical Disorientation (TD) is the inability to find one's way in the surroundings. It happens to all of us, but in some cases it can become a serious problem, impairing autonomy, self-confidence, social life and physical activity.

The goal is to obtain an EEG marker that can be used as a time-resolved signature of TD. We used a Virtual Reality navigation task.

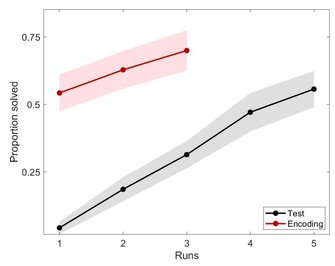
Behavioural outcomes (so far)

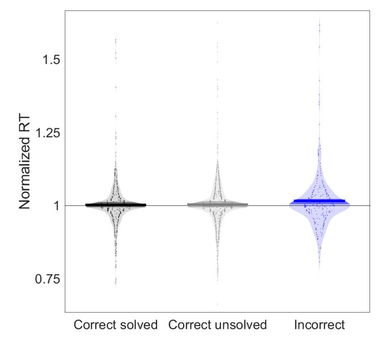
Accuracy (N=14)

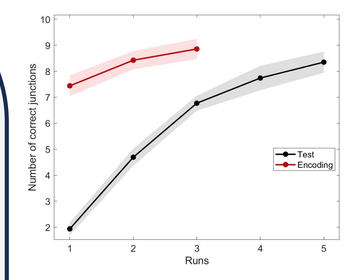
Accuracy increases with runs (learning) and declines from the encoding to the test stage (forgetting).

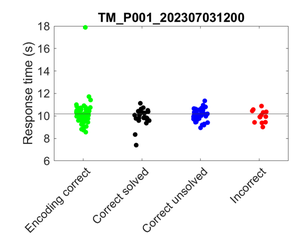
Reaction times (N=22)

No (clear) relationship between *time to take turn* and accuracy. This is true both at group level (plot right below) as well as in most individual patterns (example plot further below).









How to catch moments of disorientation before a turn is taken?

Hypothesis-driven approach

Based on the Conflict Monitoring and Cognitive Control Theory (Botvinick, 2004), competition between alternative but incompatible actions produces increase in Theta oscillatory power over fronto-central electrodes. We plan to harness on this EEG correlate to detect trials where participants are the most hesitant (e.g., disoriented?).

Reference
Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: an update. *Trends in cognitive sciences*, *8*(12), 539-546.

Data-driven approach

Machine Learning may help classify wrong vs. correct turns based on pre-decision EEG patterns, *no (theoretical) questions asked*. We plan to start simple with SVM. However, the parameter landscape (e.g., time, frequency, electrode) is vast, and maybe principled approaches based on MVPA / RSM might help. However,…

What is the ground truth for disorientation?

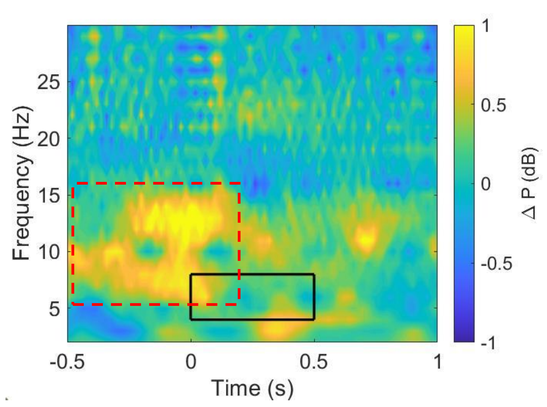
When disoriented, one can still take the right turn by chance. Can we distinguish lucky guesses made when the participant is lost, from correct turns arising from accurate memories?

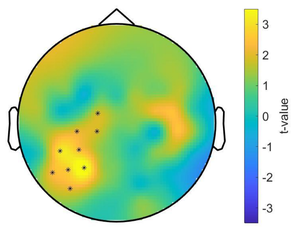
EEG outcomes (so far)

Sanity check

We followed Chrastil et al. (2022) analysis (using an N=22 dataset). We contrasted hits vs. misses (one-tail t-test) for Theta power (4-8Hz) in a 500ms post-decision temporal window (black square in TF plot below). Cluster-based permutation tests revealed a cluster of significant parietal electrodes (starred in the topoplot), replicating Chrastil et al. 2022.

Reference
Chrastil, E. R., Rice, C., Goncalves, M., Moore, K. N., Wynn, S. C., Stern, C. E., & Nyhus, E. (2022). Theta oscillations support active exploration in human spatial navigation. *NeuroImage*, *262*, 119581.





Observations

Despite the findings of Chrastil 2022 check out, there are other time windows and frequencies that differ between right and wrong turns (red dashed-line square), especially before the turn itself.

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Project: Sensory Entrainment for Improving Spatial Navigation. PI: M. Torralba