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Newly Designed Ecological Task to Assess Cognitive Map Reading Ability: Behavioral Neuro-Anatomic Correlates of Mental Navigation

Authors : Igor Faulmann, Arnaud Saj, Roland Maurer

Abstract : Spatial cognition consists in a plethora of high level cognitive abilities: among them, the ability to learn and to navigate in large scale environments is probably one of the most complex skills. Navigation is thought to rely on the ability to read a cognitive map, defined as an allocentric representation of ones environment. Those representations are of course intimately related to the two geometrical primitives of the environment: distance and direction. Also, many recent studies point to a predominant hippocampal and para-hippocampal role in spatial cognition, as well as in the more specific cluster of navigational skills. In a previous study in humans, we used a newly validated test assessing cognitive map processing by evaluating the ability to judge relative distances and directions: the CMRT (Cognitive Map Recall Test). This study identified in topographically disorientated patients (1) behavioral differences between the evaluation of distances and of directions, and (2) distinct causality patterns assessed via VLSM (i.e., distinct cerebral lesions cause distinct response patterns depending on the modality (distance vs direction questions). Thus, we hypothesized that: (1) if the CMRT really taps into the same resources as real navigation, there would be hippocampal, parahippocampal, and parietal activation, and (2) there exists underlying neuroanatomical and functional differences between the processing of this two modalities. Aiming toward a better understanding of the neuroanatomical correlates of the CMRT in humans, and more generally toward a better understanding of how the brain processes the cognitive map, we adapted the CMRT as an fMRI procedure. 23 healthy subjects (11 women, 12 men), all living in Geneva for at least 2 years, underwent the CMRT in fMRI. Results show, for distance and direction taken together, than the most active brain regions are the parietal, frontal and cerebellar parts. Additionally, and as expected, patterns of brain activation differ when comparing the two modalities. Furthermore, distance processing seems to rely more on parietal regions (compared to other brain regions in the same modality and also to direction). It is interesting to notice that no significant activity was observed in the hippocampal or parahippocampal areas. Direction processing seems to tap more into frontal and cerebellar brain regions (compared to other brain regions in the same modality and also to distance). Significant hippocampal and parahippocampal activity has been shown only in this modality. This results demonstrated a complex interaction of structures which are compatible with response patterns observed in other navigational tasks, thus showing that the CMRT taps at least partially into the same brain resources as real navigation. Additionally, differences between the processing of distances and directions leads to the conclusion that the human brain processes each modality distinctly. Further research should focus on the dynamics of this processing, allowing a clearer understanding between the two sub-processes.

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