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Investigating the relation of path integration performance and using cartographic cues inspired by grid cell properties

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Abstract:

For many human activities, such as planning, orientation and navigating, spatial information provided by cartographic visualisations plays an important role. Optimizing the design and readability of maps is a crucial research area in cartography and cognitive psychology. Maps and 3D visualisations of specific environments provide necessary information for orientation (Montello, 2001). Recent neuroscientific findings on spatially tuned cells in the brain might lead to a better map design and understanding how maps improve navigation performance (Derdikman & Moser, 2014). The maps could then be designed such that their main graphically structures are optimally adapted to the activity profile of populations of spatially tuned cells. Spatially tuned cells such as grid cells are important for the cognitive mapping of the spatial environment in the medial temporal lobe of the mammalian brain (Derdikman & Moser, 2014). Their characteristic firing patterns lead to a microstructure of a spatial map in the hippocampus, enabling individuals to self-locate and navigate in different environments (Hafting et al., 2005). One class of these spatially tuned cells in the brain are grid cells (Hafting et al., 2005). They have repeating firing fields that are characterized by a prominent sixfold rotational symmetry. Grid cell like representations were also shown in humans (Kunz et al., 2019). The activity patterns of grid cells are not generated randomly but are determined by cardinal axes provided by environmental landmarks (Julian et al., 2018; Nau et al., 2018). Several studies suggest that grid cells support path integration, which is crucial for successful navigation (Banino et al., 2018; Stangl et al., 2018). This is particular the case when no alternative navigation strategies could be applied (Bierbrauer et al., 2020). We wanted to examine the influence of an environmental design adapted by the properties of grid cells on path integration.

We investigated the influences of axes 30° and 60° apart from each other, as well as different distance measures in a round spatial environment without any boarders on path integration performance. 51 subjects conducted a screen-based path integration task in a virtual 3D spatial environment. Exemplary overviews of specific trials are shown in figure 1.

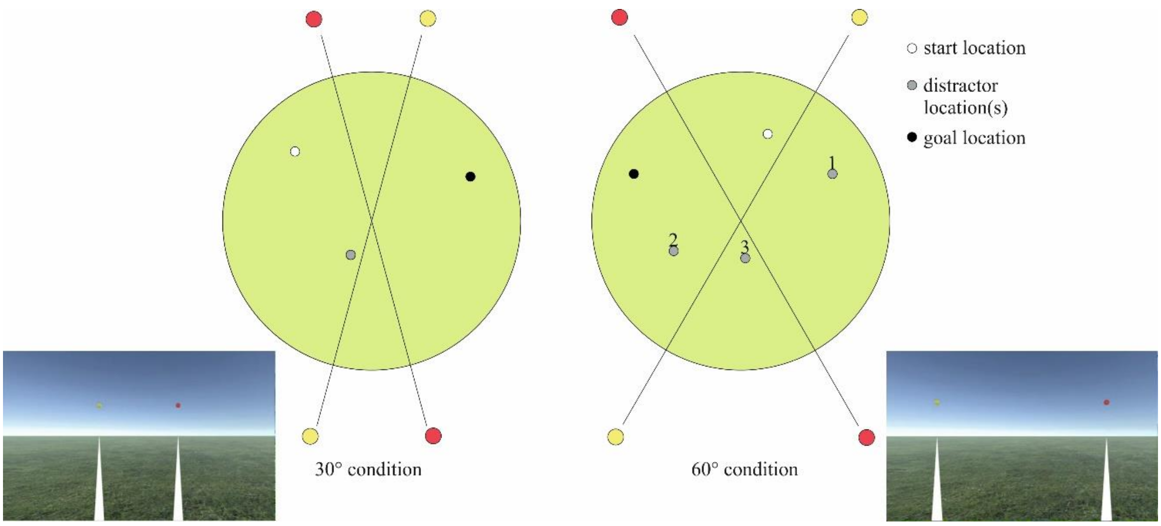

Figure 1. Exemplary overview of the experimental spatial environment and first-person perspectives. Axes, corresponding to the hexagonal activity of grid cells, were not visible during path integration task. Cylinders representing the different types of locations were visible one after another.

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We chose a within-subjects design, where half of the participants first navigated through the environment with the 60° axes and after a break through the environment with the 30° axes and vice versa. Participant's task was to navigate to different locations in this circular 3D environment. Starting in the middle of the environment participants were asked to navigate to the start location, which was disappearing while walking through it. Then participants had to navigate to one to three distractor locations, the number was pseudo-randomized over trials, and the goal location. After passing the goal location participants were asked to navigate them back to the start location and indicate the remembered location via button press. We investigated the influence of 30°/60° condition, number of distractor locations, block and different distance measurements with respect to the locations.

The analyses showed no significant effect of the 30°/60° condition and no interaction effects with number of distractor locations and block. However, we could see a significant effect of the number of distractor locations, the covariate gender as well as the distance between the middle of the arena and the start location, the minimum travelled distance between all locations and the travelled distance of the participant in this trial. The absence of any difference due to the 30°/60° condition might be due to the fact that grid cell like representations were only found in fMRI due high movement speed and up to a specific difficulty (Bierbrauer et al., 2020) and here all trials irrespective of difficulty were part of the analysis. It can be assumed that the movements in our study were possibly even slower than the effect could have become visible. In subsequent studies, the research focus therefore be directed more towards the speed factor.

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