Individual Differences in Spatial Representations and Wayfinding

Navigation is a well-specified computational problem, and solving it is vital for survival. Given these constraints, we might expect that humans differ minimally in their wayfinding capabilities. Indeed, a lack of variation is often implicitly assumed when cognitive scientists debate the existence of cognitive maps or when cognitive neuroscientists search for the neural substrates of navigation. However, in everyday life, we frequently discuss how some people get lost with some frequency, or how women ask for directions while men use maps. Indeed, it is increasingly apparent in the scientific data on navigation (and other cognitive domains) that the study of normative functioning needs to be integrated with the study of human variation, with its attendant challenges regarding experimental design and use of psychometrics. The four papers in this symposium gather together current work in cognitive science and neuroscience that aim to integrate the study of variation into the more common normative approach.

Mechanisms of Differences in Cognitive Mapping and Navigational Ability: Explorations Using Virtual Reality Manipulations

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Daily function depends on an ability to mentally map our environment. Environmental visibility and complexity can increase this challenge. Importantly, people vary dramatically in their ability to navigate flexibly and overcome such environmental challenges. In this paper, we will present experimental work targeting the mechanisms that underlie different navigational abilities, and how objective and introspective measures of ability interact to influence navigational strategy use. Using virtual reality, we manipulated environmental visibility and complexity. Participants then performed wayfinding, pointing, and route following tasks to probe cognitive map memory and navigational flexibility. Our findings reveal that individual differences in metacognition - such as perceived sense of direction - and in navigational strategy preference powerfully impact how environmental features affect spatial memory. We also gathered data on the neurocognitive foundations of these differences. Importantly, our methods highlight individualized interventions that can improve spatial learning and specify the mechanisms through which they operate.

A Meta-analysis of Sex Differences in Human Navigation Skills

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Popular sources often assume the existence of a male advantage in navigation, but the scientific data are inconsistent. This meta-analysis evaluates the literature on behavioral sex differences in human navigation. We quantify the overall magnitude of sex differences in a variety of paradigms and populations and examine potential moderators in large-scale navigation skills, using 694 effect sizes from 266 studies and a multilevel linear modeling approach. Overall, we found that male participants outperform female participants, with a small to medium effect size (d= 0.34 to 0.38). The type of task, the type of dependent variable and the testing environment significantly contribute to variability in effect sizes. Pointing and recall tasks show larger sex differences than distance estimation tasks or learning to criterion; among the dependent variables, the deviation scores associated with pointing tasks show larger effect sizes. The largest estimate was d = .55 for tasks than required coordinating indoor and outdoor views. Interestingly, studies with children younger than 13 years showed very small effect sizes (d = .15) as compared to older age groups. We discuss the implications of these findings for the study of sex differences and identify avenues for future navigation research.

Measuring Spatial Perspective Taking:
Analysis of Four Measures using Item Response Theory

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Research on spatial thinking needs reliable and valid measures of individual differences in skills. Visuospatial Perspective Taking (PT)—the ability to mentally maintain and transform spatial relationships between objects within an environment—is one kind of spatial skill that is especially relevant to navigation and building cognitive maps. However, the psychometric properties of various PT tasks have yet to be examined. The present study examines three main psychometric properties of PT tasks: 1) the reliability of two tasks developed for children but adapted in difficulty level for use in adult populations, 2) item difficulty and discriminability within and between four tasks using item response theory, and 3) relation of scores with general intelligence, working memory, and mental rotation. Results showed that two of the four PT tasks have promising psychometric properties for measuring a wide range of PT ability based on item difficulty, discriminability, and efficiency of a test information function.

Genetics and Experience Modulate Individual Differences in Navigation

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Different memory systems, dependent on separate parts of the brain, can sustain successful navigation. The hippocampus is implicated in spatial memory strategies used when finding one's way in the environment, i.e. it is allocentric and involves remembering the relationship between landmarks. On the other hand, another strategy dependent on the caudate nucleus can also be used, i.e. the response strategy, which relies on making a series of stimulus-response associations (e.g. right and left turns from given positions). Participants who use the response strategy are faster at learning navigation tasks lending themselves to using a single specified route. Young adult response learners have increased fMRI activity and grey matter in the caudate nucleus, but decreased fMRI activity and grey matter in the hippocampus. Research in my laboratory has shown that specific navigation strategies are associated with several genes, such as BDNF and ApoE, as well as hormones, such as cortisol and progesterone, but not estrogen and progesterone. Experiences dependent modulators such as age, habit, stress and rewards also modulate strategies dependent on the hippocampus and caudate nucleus. These results have important translational implications because a larger hippocampus has been associated with healthy cognition in normal aging and with a reduced risk of numerous neurological and psychiatric disorders such as Alzheimer's disease, Schizophrenia, Post-Traumatic Stress disorder and Depression.