Multiple Systems For Visuospatial Imagery

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Visuospatial imagery plays a central role in human cognition: for planning actions, as in considering how to carve a turkey; for navigation, as in imagining a route home after a walk in a new place; and for reasoning, as in plotting a movie in chess or scrabble. The *multiple systems framework* (Zacks & Michelon, 2005) proposes that different transformations can be distinguished in terms of which of several spatial reference frames is updated. Two types of transformation are particularly important for human spatial reasoning. In an *object-based transformation*, an object-centered reference frame moves relative to the viewer's egocentric reference frame and the environment-centered frame. In a *perspective transformation*, the observer's egocentric reference frame moves relative to environment-centered and object-centered reference frames. Many spatial reasoning problems could in principle be solved using either an object-based transformation or a perspective transformation—however, people appear to be adapted to use different specialized spatial transformations in different situations. This may because imagery systems construct simulations based on previous actual perceptual-motor experiences. This talk will review recent research from our group providing three types of evidence for the specialization of imagery systems: Mental chronometry, cortical stimulation, and neuroimaging.

One implication of the multiple systems view is that the amount of time it takes to solve two geometrically identical problems may differ, depending on which transformation system is used, and that this timing should reflect one's perceptual-motor experiences. An initial set of studies involving judgments about human figures provided evidence for this claim (Zacks, Mires, Tversky, & Hazeltine, 2002). Another claim of the multiple systems view is that people should tend to use different transformation systems when interacting with objects of different size and manipulability. As predicted, people appear to prefer object-based transformations when reasoning about small objects (Zacks & Tversky, in press), but prefer perspective transformations when reasoning about large spaces (Shelton & Zacks, under review).

The multiple systems view implies that judgments based on object-based or perspective transformations will share common neural mechanisms for perceptual encoding and response execution, but each will require unique processing resources for spatial reference frame updating. Support for this hypothesis comes from a cortical stimulation study in which stimulation of right superior parietal cortex transiently and selectively impaired object-based transformation performance (Zacks, Gilliam, & Ojemann, 2003). Further support has come from neuroimaging studies (Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999; Zacks, Ollinger, Sheridan, & Tversky, 2002; Zacks, Vettel, & Michelon, 2003). These studies suggest that object-based reference frame updating may depend on regions in right superior parietal cortex, whereas perspective transformations may depend on more inferior regions, particularly in the left hemisphere.

These data converge with behavioral and neuroimaging results from other laboratories in suggesting that human spatial reasoning depends on multiple specialized neural transformation systems.

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