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EDITORIAL

Introduction to the special issue on spatial learning and reasoning processes

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This issue presents the evolving understanding of *spatial cognition*. Considering individual differences in spatial problem solving has both expanded the domain of spatial thinking and led to new ways to measure spatial thinking. While there is general agreement in the field that spatial thinking is not one unitary process, there is less agreement about what cognitive processes might subserve spatial thinking.

The SILC research center has found a typology used in semantic analysis helpful in guiding research. This typology postulates two dimensions of spatial representation—thinking about *static* versus *moving* objects, and thinking about spatial relations *within* versus *between* objects. There is evidence that these two dimensions are cognitively and neurologically distinct (Chatterjee 2008). Research in this issue expands what we know about these dimensions in understanding reasoning about spatial relations at small (object-level) scales and larger (navigation-level) scales. Understanding the mechanisms underlying spatial thinking requires programmatic research that crosses disciplinary boundaries in psychology (e.g., perception, cognition, linguistics) and between the social and natural sciences. This issue offers case studies to illustrate the value of this approach. Further, the issue provides examples of the interrelationship between basic science in this area and applications to education. A central goal of our work is to use our understanding of spatial thinking to support education, particularly science, technology, engineering and mathematics education.

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A number of papers in this issue approach complex spatial thinking by looking at how humans understand the complex spatial patterns found in nature (*Atit* et al*., Harris* et al*., Hinze* et al*., Jee* et al*., and Resnick & Shipley*). An interdisciplinary approach to spatial thinking has fostered collaborations between natural science experts and cognitive scientists. It also guides a developmental approach to visualizing spatial change that spans the range from novice (or young) spatial reasoner to expert. The successes reported in this issue in the fields of geology (*Resnick* et al. *and Jee* et al.), chemistry (*Hinze* et al.) and mathematics (*Flanagan, Schultheis & Barkowsky* and *Taylor & Tenbrink*) can serve as models for how to develop our understanding of how the mind works by understanding how it grasps formal scientific descriptions of the world and how to best educate novice spatial thinkers. Concretely, this issue offers formal characterization of how humans visualize non-rigid changes (*Atit* et al. *and, Resnick & Shipley*), reviews what we know about the development of this skill in children (*Harris* et al.), examines this skill in experts, and even how it enters into the language used when thinking about folding paper (*Taylor & Tenbrink)*. This issue also explores new ways to promote spatial learning, by applying research on analogical processing. For example, *Jee* et al. show that students' learning of the geoscience concept of a *fault* can be promoted by providing them with highly alignable contrasting pairs.

The expansion of research has built on new ways of assessing spatial thinking. It has also suggested a natural learning path from action to abstraction, whereby spatial knowledge is initially grounded in embodied cognition and become more abstract through spatial processes such as gesture, sketching, analogical comparison and the use of symbols. Here, the use of spatial gestures and their informational content can help illuminate different approaches to solving the same spatial problems (*Göksun* et al.). Similarly, eye tracking can reveal strategies students use to approach spatial problems (*Hinze* et al.). Further traction in this area has been provided by new measures to assess spatial reasoning processes in young children. These help us understand the developmental trajectory (*Frick* et al.) and characterize the role of spatial experiences (*Nazareth* et al.). These new measures also allow study of higher-order spatial thinking, including the effects of language in structuring spatial schemas (*Homes & Wolff*), and the role of external symbolic systems in the solution of complex spatial problems (*Galati & Avraamides, Taylor & Tenbrink, and Wan & Newcombe*).

This issue illustrates the value of interdisciplinary approach to understanding spatial thinking. We have significantly expanded what we know about the basic science, we have developed new assessments, which are critical for studying how spatial thinking is learned and how best to support spatial thinking in education. Finally, we have offered one model for developing an interdisciplinary program that combines social and natural sciences.

Reference

Chatterjee A (2008) The neural organization of spatial thought and language. Semin Speech Lang 29(3):226–238