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The Spatial Foundations of Language and Cognition

Edited by
Kelly S. Mix, Linda B. Smith,
and Michael Gasser

04 Explorations in Language and Space

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Foreword: Space as Mechanism

Spatial cognition has long been a central topic of study in cognitive science. Researchers have asked how space is perceived, represented, processed, and talked about, all in an effort to understand how spatial cognition itself works. But there is another reason to ask about the relations among space, cognition, and language. There is mounting evidence that cognition is deeply embodied, built in a physical world and retaining the signature of that physical world in many fundamental processes. The physical world is a spatial world. Thus, there is not only thinking *about* space, but also thinking *through* space—using space to index memories, selectively attend to, and ground word meanings that are not explicitly about space. These two aspects of space—as content and as medium—have emerged as separate areas of research and discourse. However, there is much to be gained by considering the interplay between them, particularly how the state of the art in each literature impacts the other.

Toward that end, we have assembled chapters from a diverse group of scientists and scholars who represent a range of perspectives on space and language. They include experimental psychologists, computer scientists, roboticists, linguists, and philosophers. The book is divided into three sections. In the first, we address the notion of space as the grounding for abstract thought. This idea solves a number of problems. It explains how complex concepts without clear physical referents can be understood. It specifies how 'here-and-now' perception can interact with cognition to produce better problem solving or language comprehension. For example, Clark provides many excellent examples of ways that people co-opt both language and space to scaffold complex behavior. Due to this similarity in function, he contends, language and space are naturally coupled in human cognition. Ramscar, Matlock, and Boroditsky summarize a series of elegant experiments demonstrating that people ground their concepts of time in their own bodily movements. Likewise, Spivey, Richardson, and Zednik present research showing how people scan space as a way to improve recall. Together, these two chapters provide strong support for the basic idea of embodiment in cognition and, more specifically, the way movement through space is recruited by seemingly abstract cognitive processes. Mix's chapter looks forward—asking whether, if these ideas about human cognition are correct, they can be used to improve instruction in mathematics. She focuses on the role of concrete models, in particular, and asks whether they might engage a natural predisposition to ground abstract concepts in space and action.

Although spatial grounding provides a plausible explanation for higher-level processing, where does this conceptualization of cognition leave us with respect to spatial cognition in particular? As for many areas within cognitive psychology, spatial cognition was traditionally characterized in terms of logical abstractions. Research with adults has emphasized the use of propositions and linguistic frames for representing space. Developmental research has focused on how children move from concrete, egocentric views of space toward the abstract mental maps supposedly used by adults. In light of this, the claim that abstract cognition is anchored by space has a certain irony to it. Still, the same movement that questioned the grounding of other thought processes has led experts on spatial cognition to consider the role of embodiment there, too. The chapters in Section II address this issue head-on. Each grapples with the tension between established frameworks for spatial thought and mounting evidence for embodiment. Although all the authors admit a role for bodily experience, they differ in the extent to which they are willing to jettison, or even modify, traditional descriptions. But the debate itself raises critical questions about what representations are, what constitutes embodiment, and whether we need both to explain human behavior.

For example, Carlson focuses on the acquisition of spatial terminology, arguing that distance comes along for the ride as children learn a variety of spatial words—even those that are not about distance (e.g. 'above'). Distance, she posits, is part of the reference frame used for all spatial terms, and thus becomes incorporated incidentally. Similarly, Huttenlocher, Lourenco, and Vasilyeva argue that the way children encode spatial information varies depending on whether they are moving through space as they track a target. Thus, both accounts identify a role for movement in spatial cognition, but also contend that it contributes to some form of mental representation. Landau, O'Hearn, and Hoffman make an even stronger, explicit case that abstract representations are needed to complete spatial tasks, such as block design, based on their study of spatial deficits in children with Williams syndrome. In contrast, Lipinski, Spencer, and Samuelson question the need for such mental structures. They present a dynamic field model that shows how spatial language and memory for location could be connected without an intervening representation.

In Section III, we consider space as a mechanism for language acquisition—as the medium through which many words are learned, not just terms for space. Smith and Samuelson's chapter points out that spatial contiguity between word and sensory experience is likely just as powerful as temporal contiguity in promoting word learning, perhaps even more so because spatial contiguity can persist through time. However, for this mechanism to work, children would have to notice and encode spatial location along with other sensory information, like the sounds of a spoken word. Smith and Samuelson argue that research on the A-not-B error demonstrates that children do connect space and action, and this same process could become activated in word learning. Similarly, Yu and Ballard consider the way space unites word and referent, but instead of short-term memory, they focus on the role of attention. They present a series of experiments in which a robot is taught the names of objects in a picture book. This appears to hinge on joint attention between the robot and its teacher, such that spoken words co-occur with visual perception of their referents (i.e., the appropriate book illustrations), more frequently than not. Cannon and Cohen also consider the role of space in word learning, but focus on the extent to which bodily experiences (i.e., movements through space) support the acquisition of verb meanings. They make the critical point that language is grounded in space, even when the particular words are not about space.

List of Plates

Notes on Contributors

DANA BALLARD is a professor of Computer Science at the University of Texas–Austin. His main research interest is in computational theories of the brain, with emphasis on human vision. With Chris Brown, he led a team that designed and built a high-speed binocular camera control system capable of simulating human eye movements. The theoretical aspects of that system were summarized in a paper, 'Animate vision', which received the Best Paper Award at the 1989 International Joint Conference on Artificial Intelligence. Currently, he is interested in pursuing this research by using model humans in virtual reality environments. In addition he is also interested in models of the brain that relate to detailed neural codes.

LERA BORODITSKY is an assistant professor of psychology at Stanford University. Her research centers on the nature of mental representation and how knowledge emerges out of the interactions of mind, world, and language. One focus has been to investigate how the languages we speak shape the ways we think.

ERIN CANNON received a BA in Psychology from University of California, Irvine, in 1998 and a Ph.D in Developmental Psychology from the University of Massachusetts, Amherst in 2007. Her research spans from infancy to the preschool ages, and focuses on the development of action and intention understanding, action prediction, and verb learning. She is currently a postdoctoral research associate at the University of Maryland.

LAURA CARLSON is currently Professor of Psychology at the University of Notre Dame. She earned her Ph.D from the University of Illinois, Urbana-Champaign in 1994, and has been at Notre Dame ever since. Her primary research interest is in spatial language and spatial cognition. She employs empirical, computational, and psychophysiological measures to investigate the way in which the objects and their spatial relations are encoded, represented, and described. She co-edited (with Emile van der Zee) the volume *Functional Features in Language and Space: Insights from Perception, Categorization, and Development*, published by Oxford University Press. She currently serves as Associate Editor for *Memory and Cognition*, and Associate Editor for *Journal of Experimental Psychology: Learning, Memory and Cognition*, and is on the editorial boards of *Perception and Psychophysics* and *Visual Cognition*.

ANDY CLARK is Professor of Logic and Metaphysics in the School of Philosophy, Psychology and Language Sciences at Edinburgh University. Previously, he was Professor of Philosophy and Cognitive Science at the University of Sussex, Professor of Philosophy and Director of the Philosophy/Neuroscience/Psychology Program at Washington University in St Louis, Missouri, and Professor of Philosophy and

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PAUL COHEN attended UCSD as an undergraduate, UCLA for an MA in Psychology, and Stanford University for a Ph.D in Computer Science and Psychology. He graduated from Stanford in 1983 and became an assistant professor in Computer Science at the University of Massachusetts. In 2003 he moved to USC's Information Sciences Institute, where he served as Deputy Director of the Intelligent Systems Division and Director of the Center for Research on Unexpected Events. In 2008 he joined the University of Arizona. His research is in artificial intelligence, with a specific focus on the sensorimotor foundations of human language.

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Michael Ramscar received his Ph.D in Artificial Intelligence and Cognitive Science from the University of Edinburgh in 1999. He has been on the faculty at Stanford since 2002. In his research he seeks to understand how our everyday notions of concepts, reasoning, and language arise out of the mechanisms of learning and memory as their architecture develops in childhood.

Daniel C. Richardson studied psychology and philosophy at Magdalen College, Oxford as an undergraduate, and received his Ph.D in psychology from Cornell University in 2003. After a postdoctoral position at Stanford, he was an assistant professor at University of California Santa Cruz, and then a lecturer at Reading University in the UK. Currently, he is a lecturer at University College London. His research studies the speech, gaze, and movements of participants in order to investigate how cognition is interwoven with perception and the social world.

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Abbreviations

AVS	Attentional Vector Sum model
CA	Category Adjustment
CCD	charge-coupled device (camera)
DFT	Dynamic Field Theory
fMRI	functional magnetic resonance imaging
HMM	Hidden Markov Model
MA	mental age
MOT	multiple object tracking task
PF	perceptual field
PSS	Perceptual symbol system
SES	socioeconomic status
SWM	working memory field
TOM	theory of mind
VOT	Voice onset time
VR	Virtual reality
WS	Williams syndrome

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