Flusberg, S. J. & Boroditsky, L. (2011). Embodiment & Embodied Cognition. In *Oxford Bibliographies Online: Psychology*. New York: Oxford University Press. DOI: http://dx.doi.org/10.1093/obo/9780199828340-0023

# EMBODIMENT AND EMBODIED COGNITION

Stephen J. Flusberg & Lera Boroditsky
Stanford University
Department of Psychology

## TABLE OF CONTENTS

## INTRODUCTION

Embodied cognition (EC) is a movement within the field of cognitive science that seeks to explore the ways in which cognitive processes may be grounded in the sensorimotor capabilities of an agent that is situated in a complex, real-world environment. On this view, the body of the agent structures and constrains the nature of the mind, perceiving and thinking are largely done in the service of action that is carried out in real-time, and cognition more generally emerges from the dynamic interplay between the organism and its environment. In practice, there is no single unified theory of EC. Rather, EC may be thought of as a general research program or framework that consists of a variety of related claims, methodologies, and approaches to studying cognition and behavior. Interest in EC has developed among all the major subfields of cognitive science, including linguistics, cognitive and developmental psychology, neuroscience, artificial intelligence and robotics, philosophy, and anthropology. Research on EC can be found in most of the leading journals representing these fields. Some researchers focus on how cognition is situated in the real world, and must rapidly unfold in the service of pragmatic goals and actions. This may include offloading certain cognitive tasks onto the environment itself, such as using pencil and paper to help perform mathematical calculations. These ideas have led some theorists to suggest that the mind literally extends into the environment and that cognition can only be understood as a function of the dynamically coupled agent-environment system. Other researchers focus more on the cognitive abilities of the agent in isolation and investigate how higher-level cognitive processes such as language and abstract thought may be grounded in lower-level sensorimotor systems in the brain. Still others look at how features of the body itself can figure into various cognitive operations, for example through the use of gesture. EC is often presented as an alternative to classical approaches within cognitive science, which have attempted to describe cognition in terms of discrete, amodal, symbolic information-processing mechanisms divorced of any particular physical instantiation. However, even among proponents of EC there are a range of perspectives on such foundational issues as the nature and function of representation in any theory of the mind. That being said, insights from EC provide new ways of conceptualizing many different subjects, from perception and mental imagery to language and abstract thought.

## GENERAL OVERVIEWS

Though EC is a relatively recent movement in the cognitive sciences, there are already a number of accessible books and articles that would serve as general and thorough introductions to the wide range of ideas that are currently under investigation. The article “Embodied Cognition” in the Internet Encyclopedia of Philosophy provides an accessible online introduction to EC. Varela et al. 1991 is often regarded as the book that kicked off the modern EC movement in cognitive science, and Gibbs 2006 presents a detailed summary of much of the empirical support for embodiment in different areas of research in psychology. Barsalou 2008 offers a more concise overview of the evidence that higher-level cognition is grounded in perceptual and motor systems in the brain. Clark 1997 and Shapiro 2011 provide broader philosophical overviews of the EC framework, while Chemero 2009 outlines a methodological and philosophical framework for a more radical form of EC that does not include mental representations at all. Wilson 2002 puts forth the idea that EC actually consists of several somewhat orthogonal claims that should be investigated and evaluated independently. Scholars interested in more applied programs such as robotics or artificial intelligence should look to Brooks 1999, which summarizes the behavior-based approach to robotics that is grounded in real-world navigation and behavior.

Barsalou, L. (2008). Grounded Cognition. *Annual Review of Psychology 59*, 617-645.

> This review article summarizes the theoretical and empirical support for the view that conceptual knowledge is supported by modality-specific neural mechanisms rather than amodal symbol systems. Barsalou is a leading figure in this area of research.

Brooks, Rodney A. (1999). *Cambrian Intelligence: The Early History of the New AI*. Cambridge, MA: The MIT Press

Collection of essays outlines the behavior-based robotics program in artificial intelligence that views cognition as an emergent consequence of perception and action systems. Book is divided into two halves, the first focused on the engineering of these robots and the second focused on the philosophy of this approach to AI. Behavior-based robotics stands in stark contrast to classical approaches in artificial intelligence that focus on explicit cognitive and representational processes.

Chemero, A. (2009). *Radical Embodied Cognitive Science.* Cambridge, MA: MIT Press.

This book outlines a research program for a radical embodied cognitive science based on the tools of dynamical systems theory and the ontology of Gibson's 1979 ecological approach to perception (cited in Perception). Chemero suggests that this book should be viewed as analogous to Fodor's classic, *The Language of Thought,* which outlined the research program for the classic, computational approach to cognitive science.

Clark, A. (1997). *Being There: Putting Brain, Body, and World Together Again*. Cambridge, MA: MIT Press.

This highly accessible book argues that cognition emerges from the dynamic interplay between the brain, the body and the environment. Author's position is notable for maintaining some of the conceptual tools of classical approaches to cognitive science (e.g. representation) while at the same time highlighting that cognition is necessarily embodied.

Embodied Cognition. Cowart, M. *The Internet Encyclopedia of Philosophy*, ISSN 2161-0002, http://www.iep.utm.edu/

This online article provides a succinct overview of the EC research program in cognitive science, touching on the motivations for the movement, its general characteristics, and how it compares and contrasts with more traditional approaches.

Gibbs, R. (2006). *Embodiment and Cognitive Science*. Cambridge, UK: Cambridge University Press.

Author summarizes the empirical and theoretical support for the role of embodiment across a wide variety of topics in cognitive science, from perception and action to concepts and language, reasoning and development.

Shapiro, L. (2011). *Embodied Cognition.* New York, NY: Routledge.

This philosophical overview compares and contrasts the traditional approaches to cognitive science with various arguments the EC literature. Isolates and critiques three major claims of EC: (1) the structure of the body constrains the concepts an organism can acquire, (2) an organism's interaction with the environment replaces the need for classical representations, and (3) the body and world are (partially) constitutive of the cognitive system as a whole.

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience,* MIT Press: Cambridge, MA

This is perhaps the founding text of the contemporary EC movement. In it, the authors present their *enactive* view of cognition that highlights the dynamic, spontaneous aspects of embodied experience that bridges the subjective/objective duality inherent in traditional approaches to cognition.  The book is notable for its unique reliance on Eastern, Buddhist approaches to mind and experience.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review* 9, 625.
Author outlines six different claims that have been investigated by supporters of EC and evaluates each of them independently on the basis of empirical support.  This brief paper serves as a wonderful introduction to the wide variety of somewhat independent ideas being explored in the EC movement.

## TEXTBOOKS

While there is no standard textbook on Embodiment, there are number of books that could serve as a primary source for an undergraduate or graduate seminar on EC.  These works are primarily collections of articles by leading scholars in the field that explore many different aspects of embodiment research and theory.  Gibbs 2006 and the Handbook of Calvo and Gomila 2008 would serve as good texts for an upper-level undergraduate or graduate seminar on EC.  Pecher & Zwaan 2005 and Semin & Smith 2008 would be most useful for a seminar focused on how higher-level cognitive processes are grounded in perceptual and motor systems.  Port & Van Gelder 1995 and Thelen & Smith 1994 are well suited to a course focused dynamical systems theories of embodiment, with the latter being most useful for a course on developmental approaches.  The Cambridge Handbook of Situated Cognition would work well for a class focused on situated and distributed approaches to cognitive systems.

Cambridge Handbook of Situated Cognition. New York: Cambridge Univ. Press, 2008.
A collection of articles that offer a broad introduction to research on *situated cognition*, the view that many cognitive processes can only be fully understood as they unfold in a particular environmental context under particular real-time constraints.

Embodied Grounding: Social, Cognitive, Affective, and Neuroscientific approaches, eds. G.R. Semin, E.R. Smith. New York: Cambridge Univ. Press, 2008.
A collection of articles that explores how embodiment may influence, constrain, and illuminate research in a variety of psychological and neuroscientific domains.

Gibbs, R. (2006).  *Embodiment and Cognitive Science*.  Cambridge, UK: Cambridge University Press.
Author summarizes the empirical and theoretical support for the role of embodiment across a wide variety of topics in cognitive science, from perception and action to concepts and language, reasoning and development.

Handbook of Cognitive Science: An Embodied Approach. Eds. Calvo P, Gomila A. Amsterdam: Elsevier Science; 2008.
This handbook would serve as a wonderful text for a seminar on EC.  It contains many articles that provide an overview of the issues taken up by researchers and thinkers involved in the EC movement.

Pecher, D. & Zwaan, (2005) *Grounding Cognition: The Role of Perception and Action in Memory, Language, and Thought*.  New York: Cambridge Univ. Press
A collection of articles by leading scholars that explores how perceptual and motor capabilities may underlie higher-level cognitive processes such as language and conceptual knowledge.

Port, R. F. & van Gelder, T. (1995). *Mind as motion: Explorations in the dynamics of cognition*. Cambridge, MA: MIT Press.

A collection of articles by leading scholars offering a variety of perspectives on how cognitive processes might be understood from a dynamical systems perspective.

Thelen, E. & Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*, MIT Press: Cambridge.

This book offers a broad but detailed introduction to the dynamical systems view of developmental psychology, with an emphasis on how cognitive processes naturally emerge over the course of development based on how the perceptual and motor capabilities of an infant or child interact with the physical environment.

## ORIGINS

The modern EC movement has rich roots that can be traced back as far as the ancient Greek, Indian, and Chinese philosophers who discussed the dynamic nature of thought and the necessary unity of mind, body and world. Contemporary scholars have been more directly influenced by several distinct fields of inquiry, including American functionalist and pragmatist philosophy, continental phenomenology, cybernetics, ecological psychology, and cognitive linguistics, among others. Dewey 1896 and James 1976 represent some of the most influential work in the American functionalist tradition, which emphasized the relationship and continuity between the organism and the natural world. Heft 2001 traces the ways in which this work set the stage for the ecological psychology of Gibson 1979 (cited in Perception). Bateson 1979 presents a related view of self-organizing mental processes that arose from his involvement in the cybernetics movement of the mid-20th century and highlights the dynamic unity of mind and world. Ryle 1949 suggests mental processes such as volition, emotions, and imagery should not be understood in terms of special events in the mind or head, but rather as complex, emergent behaviors of organism as a whole. This “logical behaviorist” view is echoed in contemporary embodied theories, which suggest that perception and language, for example, should be understood as complex, temporally extended forms behavior. The continental phenomenology of Heidegger 1972 and Merleau-Ponty 1945 focused on the ways in which our experience is necessarily structured by our bodies and the ways in which we are situated in environment. Dryfus 1972 was inspired in part by this approach to philosophy, and uses it to form the foundation of his criticism of early artificial intelligence. Vygotsky 1978 set the stage for later work on situated cognition, which focuses on the ways in which being embedded in a particular physical, social and cultural context are vital for the development of higher-level cognitive abilities.

Bateson, G. (1979). *Mind and Nature: A Necessary Unity (Advances in Systems Theory, Complexity, and the Human Sciences)*. Hampton Press.

Advocates the view that the mind, body, and environment should be understood as a singular, self-organizing cognitive system. A leading figure in the mid-20th century cybernetics movement, which emphasized the role of dynamic feedback loops in self-controlled systems (like cognitive organisms). This brief, dense book explores his views on these topics and has inspired contemporary work on dynamical systems and embodied views of cognition.

Dewey, J. (1896). The Reflex Arc Concept in Psychology. *Psychological Review 3*, 357-370.

In this classic paper, Dewey argues against the prevailing view (which still dominates most of cognitive science) that human behavior can be sensibly decomposed into separate “stimuli” and

"responses." Instead, Dewey suggests that behavior can only be understood as a dynamic process that unfolds over time in relation to what we are acting on in the environment.

Dryfus, H. (1972). *What computers can't do: The limits of artificial intelligence*. New York: MIT Press
Inspired by the continental philosophy of Heidegger and Merleau-Ponty, author criticizes "good old fashioned artificial intelligence" (GOFAI); specifically the view that cognition should be modeled as explicit algorithmic operations over symbolic representations. Author forcefully argues that the GOFAI approach fails to capture even the most basic aspects of human behavior, which involve the ability to act in a dynamically changing natural environment.

Heft, H. (2001). *Ecological Psychology in Context: James Gibson, Roger Barker and the Legacy of William James's Radical Empiricism*. Mahwah, NJ: Lawrence Erlbaum.
Author traces the roots of ecological psychology back to the functionalist, empiricist philosophy of William James. Offers an insightful and important historical look at ecological approaches to psychology, which have inspired many contemporary EC researchers.

Heidegger, M. (1972). *Being and Time*. New York: Harper & Row
In this classic of continental philosophy, Heidegger argues that the foundation of existence is the fact that we are embedded in a natural world that we have knowledge to act on. This pragmatic knowing-how provides the very basis for our being.

James, W. (1976). Essays in radical empiricism. Cambridge: Harvard University Press.
This collection of essays represents the approach to philosophy developed later in James' career that argued against a duality of body and world. Instead, he puts forth a metaphysics of *pure experience* (often described as neutral monism) where the perceiver and the world he perceives are inextricably bound together as a singular reality. An influence of this approach can be seen in Gibson's 1979 ecological approach to perception. Originally published in 1912.

Merleau-Ponty, M., 1996, *Phenomenology of Perception*, Trans. Colin Smith. London and New York: Routledge. From the French original of 1945.
Merlea-Ponty has had a great deal of influence on contemporary thinking regarding embodiment (e.g. Lakoff & Johnson 1999, cited in Abstract concepts). His approach to phenomenology emphasized that the body is a ubiquitous feature of our experience of the world, and that all of perception and action is shaped and constrained by the structure of our bodies. This book is represents the most thorough exposition of his thinking on this matter.

Ryle, G. (1949). *The Concept of Mind*, The University of Chicago Press: Chicago, IL.
Author argues it is a *category mistake* to treat mental phenomena such as thoughts and feelings as belonging to the same logical category as physical phenomena like objects. This mistake leads people to posit a mystical realm in the head where such mental phenomena reside. Instead, mental phenomena should be seen as complex, dynamic modes of behavior that an agent engages in.

Vygotsky, L.S. (1978). *Mind and society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
Vygotsky emphasized that language, thought, and problem solving all develop in a situated, cultural setting under the guidance of adults in the community. His view of higher-level cognition as an emergent consequence of social development has influenced contemporary views of

situated cognition and embodied learning theories. This book is a selection of essays that been translated into English and updated by a collection of expert scholars.

## PERCEPTION

Traditional approaches to visual perception often begin with the assumption that the information available to the perceptual system consists of a pair of noisy, ambiguous, degraded two-dimensional images projected onto the retinas. On this view, visual perception is the process whereby this retinal image is enriched into a detailed, stable internal representation of the outside world. Marr 1982 is widely regarded as the core text in support of this view, though the idea itself goes back much farther and can be found in the work of Helmholtz and others. Embodied approaches to perception generally start by challenging the assumption that the information available to the perceptual system is limited to a noisy, snapshot retinal image. Instead, they emphasize that perception is an active process, not a passive one; organisms that perceive are mobile and move their eyes, heads, and bodies in order to explore the world and pick up relevant information. By situating perception in the context of the actions of the embodied agent, it may be possible to understand perceptual abilities without positing as many (or any) enrichment processes. On this view, instead of building up a detailed representational model of the world in the mind, the world serves as its own model. This framework is most famously associated with Gibson 1979 and his ecological approach to perception. Fodor & Pylyshyn 1981 criticized this approach, suggesting that it did not take into account many of the most difficult problems in understanding perception, which can only be solved by positing specific representational machinery. Turvey et al. 1981 is a response to this article, defending Gibson and offering a more rigorous articulation of the ecological perspective based on natural laws of perception. Ballard 1991 offers an interpretation of the embodied approach from an artificial intelligence point of view, emphasizing that active, mobile visual mechanisms (e.g. eye gaze) can reduce the representational burden that a visual system must endure while perceiving. More recently, the sensorimotor contingency theory of O'Regan & Noë, 2001 and Noë 2004 has described perception as a species of action that depends on implicit knowledge of how the information reaching the visual system changes in relation to motor actions. Proffit 2006 suggests that other factors such as the current physiological state of the organism also influence how the world is perceived. Norman 2002 tries to account for both traditional and ecological approaches to vision by associating each with a different visual processing stream in the brain.

Ballard, D. H. (1991) Animate vision. *Artificial Intelligence, 48*:57–86.

Author outlines an approach to modeling visual perception in an artificial intelligence system that includes active components such as gaze control mechanisms that move the sensor (camera) in response to visual stimuli. These processes and others, such as allowing the system to learn about the visual world, are shown to dramatically reduce the computational costs for successful machine vision.

Gibson, J. J. (1979). *The ecological approach to visual perception.* Lawrence Earlbaum: Hillsdale, NJ

Author suggests that perception should be understood in relation to the body and motor capabilities of an agent embedded in a particular environment. The information available to a mobile agent in the optic array is rich and possesses invariant features that specify directly what the environment affords the agent. Radical departure from traditional approaches to perception that rely heavily on inferential and representational mechanisms.

Marr, D. (1982). *Vision*. San Francisco, CA: Freeman.

Author articulates the classic, computational approach to perception along with the influential 3-levels approach to understanding a cognitive system. Suggests that the goal of the visual system (computational level theory) is to transform the noisy 2D image on the retina into a fully 3D symbolic representation of *what* is *where* in the environment. It then offers a first step towards understanding how the brain could accomplish this feat (representational level theory).

Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspectives on Psychological Science*. 1(2), 110-122.

Author summarizes research from his lab and others suggesting that our perception of the world is influenced by (and is always in relation to) our current ability to engage in certain actions. For example, hills look steeper to people who are tired or wearing a heavy backpack because it would be harder for them to actually climb the hill.

Noë, A. (2004). *Action in Perception*. MIT Press: Cambridge, MA

A book length philosophical treatment of the theory that perception is particular mode of exploration of the environment that draws on implicit knowledge of sensorimotor contingencies. Suggests that touch, not sight, is the paradigmatic perceptual sense, and that vision itself should be understood as a form of touch.

Norman, J. (2002). Two visual systems and two theories of perception: an attempt to reconcile the constructivist and ecological approaches. *Behavioral and Brain Science, 25*, 73-144.

Author suggests that knowledge of the neuroscience of vision (i.e. the *what* and *where* pathways) may resolve the debate between traditional and embodied ecological approaches to vision. Equates the object identification properties of the ventral system with the traditional, constructivist approach and the capacity of the dorsal system to translate visual input directly into visually guided behavior with the ecological approach.

O'Regan, J. K. & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences, 24*, 939-1031.

Authors defend the sensorimotor contingency theory of visual perception and consciousness. Suggest that perceivers learn the contingent relationships between their movements, the movement of objects in the world, and the changing patterns of light reaching the visual system (or patterns of airwaves reaching the auditory system in the case of hearing). Perceptual awareness arises when an agent is exercising their mastery of these contingencies as they interact with the world.

Fodor, J., & Pylyshyn, Z. W (1981). How direct is visual perception?: Some reflections on Gibson's "ecological approach" *Cognition, 9* (2), 139-196

Authors argue that the ecological approach to vision is vastly under-constrained and cannot successfully explain the nature of perception. They suggest that people cannot directly perceive objects (or affordances) in the environment by detecting invariant features of the optic array because there is no way to constrain the possible nature of these invariances (e.g. to see a shoe you would have to detect the shoe invariant, but this is tautological).

Turvey, M. T., Shaw, R. E., Reed, E. S., & Mace W. M. (1981). Ecological laws of perceiving and acting: In reply to Fodor and Pylyshyn (1981) *Cognition, 9* (3), 237-304

Authors reply to Fodor & Pylyshyn 1981 suggesting that the ecological approach to visual perception can be suitably constrained to meaningfully account for the nature of vision by looking

for certain ecological laws that define the invariants that may be detected by a particular perceiver.

## DEVELOPMENT

According to most embodied accounts, perceptual development is inextricably bound up with motor development; perception is an active process that unfolds in the service of, and in relation to the actions that the perceiver is engaging in. Researchers have explored various general and specific ways in which motor development and motor actions influence and shape different aspects of perceptual (and conceptual) development. Gibson 1988 provides a broad overview of much of the early empirical and theoretical research on this topic, including a detailed summary of her pioneering work on the visual cliff. Held & Hein 1963 represents a classic experiment in this vein, demonstrating that cats only develop normal perceptual abilities if they are free to control their own motor behavior as they experience their surroundings. Needham 2000 and Soska et al. 2010 provide experimental evidence that motor development (in exploratory behavior and self-sitting) drives the ability to segregate objects and infer 3D structure. Herbert et al. 2007 demonstrates that the onset of independent locomotion (i.e. crawling) is associated with more flexible memory for perceived actions. Smith 2005 shows that the actions toddlers engage in when interacting with objects influences how they categories those objects, while James 2010 shows that practice writing letters leads to enhanced activation in the visual association cortex of preliterate children. Together, these articles convey the various ways in which motor development and motor actions can drive the development of certain perceptual and conceptual behaviors.

Gibson, E. J. (1988). Exploratory Behavior in the Development of Perceiving, Acting, and the Acquiring of Knowledge. *Annual Review of Psychology, 39,* 1-42

Author reviews theoretical and empirical work that infants learn about the environment through exploration, but that their motor skills constrain what information they are able to pick up at any given moment. Thus motor, perceptual, and cognitive development are inextricably linked throughout the learning process.

Held, R. & Hein, A. (1963) Movement-produced stimulation in the development of visually guided behavior. Journal of Comparative and Physiological Psychology 56:872–76.

In this classic experiment, pairs of kittens were exposed the same visual experience from birth in specialized pens, but only one of them was free to control their own movements. The other kitten was harnessed in such a way that the movements of first cat determined its motion. Only the cats that controlled their own movements developed normal perceptual abilities.

Herbert, J., Gross, J., & Hayne, H. (2007). Crawling is associated with more flexible memory retrieval by 9-month-old infants. Developmental Science, 10(2), 183-189.

In this study, infants observed an experimenter demonstrate a target action with a novel object, and were tested one day later on their ability to reproduce the action. Only infants who could crawl already were able to reproduce the action when tested with a different stimulus in a different context. Demonstrates that the onset of independent locomotion is associated with more flexible memory retrieval.

James, K.H. (2010). Sensorimotor experience leads to changes in visual processing in the developing brain. Developmental Science, 13(2), 279-288.

A brain-imaging study that compared brain activation patterns in preliterate preschool children before and after different letter-learning conditions: a sensorimotor group practiced printing letters during the learning phase, while the control group practiced visual recognition. Only children in the sensorimotor group showed enhanced brain activation in visual association cortex after training. Supports the idea that sensorimotor experience augments processing in the developing visual system.

Needham, A (2000). Improvements in object exploration skills may facilitate the development of object segregation in early infancy. *Journal of Cognition and Development, 1,* 131-156.

Three experiments investigated 3.5-month-old infants ability to segregate two adjacent objects. The results demonstrated that infants who engaged in more active exploration of the display were better able to segregate the objects.

Smith, L.B. (2005). Action alters shape categories. Cognitive Science, 29, 655-679

Two experiments show that action alters the shape categories formed by 2-year-olds. Specifically, moving an object horizontally (or vertically) defines the horizontal (or vertical) axis as the main axis of elongation and systematically changes the range of shapes seen as similar and moving an object symmetrically (or asymmetrically) also modifies shape categories.

Soska, K.C., Adolph, K.E., & Johnson, S.P. (2010). Systems in development: Motor skill acquisition facilitates three-dimensional object completion. *Developmental Psychology, 46(1),* 129-138.

Authors explore how infants' 3D object completion abilities emerge in conjunction with developing motor skills. Infants' self-sitting experience and visual–manual exploratory skills predicted looking at a novel, incomplete object on a habituation task, while self-sitting facilitated infants' visual inspection of objects when they manipulated them. The results are framed within a developmental systems approach, wherein infants' sitting skill, multimodal object exploration, and object knowledge are linked in developmental time.

## AFFORDANCES

According to the embodied perspective, perception is largely accomplished in the service of action; we perceive the world in terms of how it supports and structures our ability to act within it. Gibson 1979 (cited in Perception) introduced the concept of an *affordance* to suggest that what an organism perceives is what the environment offers or affords the perceiver. The specifics of what the environment affords are understood to be relative to the perceiver, a point elaborated on by Chemero 2003. Indeed, Warren 1984 described an affordance as the functional utility of a feature of the environment relative to an organism's motor capacities. For example, a stair might afford normal bipedal stepping for an adult, but the same stair would afford quadrupedal climbing for a toddler. Warren 1984 found that participants could accurately identify whether a stair afforded stepping or climbing simply from observing an image of a stair projected onto the wall. Further, these judgments were made based on a body-scaled ratio of the participant's leg-length to stair riser height. Mark 1987 extended this work and found that eye-height scaled information was also important for affordance perception. Research has found that many affordances can be directly expressed in terms of such body-scaled ratios. For example, the ability to fit a hand through an aperture was explored by Ishak et al. 2008. Other affordances may only be accurately perceived when the observer is in motion, as Oudejans et al. 1996 demonstrated in the case of judging whether a fly ball is catchable. Moreover, our perception of the world can vary in relation to how difficult it would be to engage in a particular action, our physiological state, and our recent motor experience. Proffitt et al. 1995 found that participants judged hills to be much steeper than they actually were, an effect that increased with fatigue. Proffitt et al. 2003 found that distances appeared farther away when participants wore a heavy backpack, and Witt & Proffitt 2005 found that softball players perceived softballs to be larger when they had a better batting average in an earlier game.

Chemero, A. (2003). An outline of a theory of affordances. *Ecological Psychology, 15*(2), 181-195.

Author attempts to build on Gibson 1979's concept of affordances. Describes affordances as *relations* between the abilities of animals and features of the environment. Thus, they are real and perceivable, but not properties of the environment (ambient optic array) or the animal in isolation.

Ishak, S., Adolph, K. E., & Lin, G. C. (2008). Perceiving affordances for fitting through apertures. *Journal of Experimental Psychology: Human Perception and Performance, 34*(6), 1501-1514.

Several experiments demonstrated that participants were accurate about judging what size hole they could fit their hand through to grab at a target. Participants were accurate when making judgments about their non-dominant hand as well, and could adapt quickly to a change in effector size due to wearing a hand-enlarging prosthesis.

Mark, L. S. (1987). Eyeheight scaled information about affordances: A study of sitting and stair climbing. *Journal of Experimental Psychology: Human Perception and Performance 13*(5), 361-70.

Author suggests that people use eye-height scaled information to make affordance judgments about climbing stairs and sitting on things. Participants wore blocks on their feet and judged whether they could sit on a seat without climbing and climb a stair in the normal fashion, leading to underestimation of seat height for sitting and overestimation of riser height for stair climbing. After some experience with the blocks, accuracy improved.

Oudejans, R. R. D., Michaels, C. F., Bakker, F. C., & Dolné, M. A. (1996). The relevance of action in perceiving affordances: Perception of catchableness of fly balls. *Journal of Experimental Psychology: Human Perception and Performance, 22*(4), 879-891.

Experiments demonstrated that observers who were moving were more accurate at judging whether a fly ball was catchable, even when their vision was occluded after the first part of the observation of the ball trajectory.

Proffitt, D. R., Bhalla, M., Gossweiler, R., & Midgett, J. (1995). Perceiving geographical slant. *Psychonomic Bulletin & Review, 2*, 409-428.

Authors investigated participants' ability to judge the inclination of real and virtual hills by (1) providing verbal estimates, (2) adjusting a representation of the hill's cross-section, and (3) adjusting a tilt board with their unseen hand. Geographical slant was overestimated according to the first two measures, but not the third, and apparent slant increased with fatigue. Conclude that perceived geographical slant modulated by the ability to act on the environment.

Proffitt, D. R., Stefanucci, J., Banton, T., & Epstein, W. (2003). The role of effort in perceiving distance. *Psychological Science, 14,* 106-112.

Authors found that egocentric distances appeared greater when people were wearing a heavy backpack or following a visual-motor adaptation that reduced the anticipated optic flow coinciding with walking effort. Suggests that we perceive the world in relation to our ability to act in it.

Warren, W.H. (1984). Perceiving Affordances: Visual Guidance of Stair Climbing. *Journal of Experimental Psychology: Human Perception & Performance, 10*(5), 683-703.

Author proposes that an affordance is determined by the fit between properties of the environment and the organism and can be characterized by optimal points, where the action is most comfortable or efficient, and critical points, where a phase transition to a new action occurs. Experiments demonstrated that participants could accurately identify these points, and that this judgment is based on a body-scaled ratio of leg length to stair riser height.

Witt, J. K. & Proffitt, D. R. (2005). See the ball, hit the ball; Apparent ball size is correlated with batting average. *Psychological Science, 16,* 937-939.

Authors approached players in a local soft ball league after a game and asked them to indicate: (a) how big a softball was (by choosing a circular image that matched their memory for how big the ball looked), and (b) how they performed in terms of batting during the game. Results demonstrated that apparent ball size and batting average were positively correlated.

## OBJECTS

As we move around the world in our daily lives, we do not merely experience raw sensations, but an environment filled with meaningful objects and events. Understanding how we perceive objects has become a major field of study for vision scientists. From the EC perspective, seeing an object involves perceiving how that object affords a particular action. Several researchers have suggested that these object-based affordances are represented by or instantiated as action plans in the motor systems of the brain. On this view, part of what it means to see an object is to know how, and be prepared to interact with it. Evidence in support of this view comes from a variety of behavioral and neuroimaging studies. Tucker & Ellis 1998, Ellis & Tucker 2000 and Fischer & Dahl 2006 all demonstrate that participants' response times and error rates are modulated by the affordances of an object in the display or task environment, even when they are making a response that has nothing to do with this affordance information per se (e.g. judging whether an object is right-side-up or upside-down). Helbig et al. 2006 found that participants were more accurate in naming a briefly presented object if they had previously been presented an object that afforded the same manual interaction. Chao & Martin 2000, Grèzes & Decety 2002 and Grèzes et al. 2003 all demonstrate that observing and naming manipulable objects leads to consistent activation in motor brain regions.

Chao, L. L. & Martin, A. (2000) Representation of manipulable man-made objects in the dorsal stream. *Neuroimage, 12*, 478-484.

Authors conducted a functional MRI experiment to explore neural correlates associated with viewing and naming different categories of objects. Viewing and naming tools selectively activated left ventral premotor cortex, which may be homolog of area F5 in monkeys, where single neuron recording experiments have shown similar results. Viewing naming tools also activates left posterior parietal cortex, another region involved in object use.

Ellis, R. & Tucker, M. (2000). Micro-affordance: the potentiation of components of action by seen objects. *British Journal of Psychology, 91*, 451-471.

In one experiment, participants made either a power or precision hand grasp action in response to an auditory stimulus while viewing objects in a box that would require either a power or precision grip to interact with. In another experiment, the manual action was a clockwise or counterclockwise wrist rotation. Participants were faster to respond when the manual action was congruent with the affordance of the seemingly irrelevant object stimulus.

Fischer, M. H. & Dahl, C. C. (2006). The time course of visuo-motor affordances. *Experimental Brain Research, 176*(3), 519-524.

In this study, subjects responded with left and right hands when a dot at the center of the screen changed color. Behind the dot in the display was a (task-irrelevant) cup rotating in the depth plain. The orientation of the handle of the cup affected response times in a predictable manner; for example, participants were faster to press the left button when the handle of the cup happened to be oriented left.

Grèzes, J., & Decety, J. (2002). Does visual perception of object afford action? Evidence from a neuroimaging study. *Neuropsychologia, 40*, 212-222.

Authors conducted a PET imaging study to investigate neural activation when participants looked at, imagined grasping, named, and generated action verbs associated with tools and non-objects. Common activation found in occipito-temporal junction, inferior parietal lobule, supplementary motor area, and pars triangularis in inferior frontal gyrus. Findings support the idea that motor representation is an integral component of the visual perception of objects.

Grèzes, J., Tucker, M., Armony, J., Ellis, R., Passingham, R. E. (2003). Objects automatically potentiate action: An fMRI study of implicit processing. *European Journal of Neuroscience, 17*, 2735-2740.

In this experiment, participants categorized objects as natural or man-made using a special response device (possible responses: grasp and pinch) while undergoing functional MRI. Participants faster to respond when the affordance of the object matched the response grasp type. This compatibility effect covaried with neural activation in parietal, dorsal premotor and inferior frontal cortex, areas known to be involved with motor actions towards objects.

Helbig, H. B., Graf, M., & Kiefer, M. (2006). The role of action representations in visual object recognition, *Experimental Brain Research, 107*(2), 221-228

Authors presented participants with images of two objects in quick succession. The task was to say the names of the two objects out loud in the order of their presentation. Participants were more accurate in naming the second object when similar actions were required to make use of two objects (e.g. pliers and a nutcracker).

Tucker, M. & Ellis, R. (1998). On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology: Human Perception and Performance. 24*(3), 830-846.

Authors investigated whether observing an object led to the potentiation of particular motor responses. Participants had to make a left or right-handed button press to indicate whether the object was upright or inverted. Subjects faster to respond when hand of response matched left/right affordance of the object (e.g. saucepan with handle on left, left button press).

## MENTAL IMAGERY

Mental imagery refers to the ability to visualize something in your "mind's eye" or hear something in your "mind's ear." These common phrases point to the apparent (quasi) perceptual character of imagery. Kosslyn et al. 2006 summarizes the theoretical, behavioral, and neuroscientific research in support of the view that (visual) mental images are represented in a pictorial, depictive, image-like format in perceptual brain regions. Pylyshyn 2003 offers an opposing view, that mental images are represented in a propositional, symbolic format (and that a pictorial format would imply an scientifically untenable inner homunculus that would have to "view" the mental images). Kosslyn and Pylyshyn argued about this point in the scientific literature throughout the 1970s and 80s in what has become known as the "imagery debate." However, specifying the format of a representation is somewhat orthogonal from specifying the system that instantiates the representation. On this matter, Pylyshyn would acknowledge that the same brain systems that support perception also support imagery. Other theorists have suggested alternative accounts of imagery that bypass the traditional debate over format. Shepard 1984 advocates a *resonance* metaphor for all internally generated representations (e.g. imagery, dreaming, hallucinations), based in part on extending Gibson's 1979 (cited in Perception) ecological approach to perception to account for a wider range of phenomena. Thomas 1999 offers a similar view. Thus, the embodied view suggests that mental imagery is constituted by the (covert, partial) reinstantiation of the same set of perceptual-motor processes that would be engaged during the actual performance of a given action or perception of a given object. This is often described as mental *simulation*.

Kosslyn, S. M., Thompson, W. L., & Ganis, G. (2006). The case for mental imagery. New York: Oxford Press.

> Authors suggest that mental images are represented in a pictorial, depictive, image-like format in perceptual brain regions. They summarize the theoretical and empirical work in support of this theory and argue against alternative viewpoints.

Pylyshyn, Z.W. (2003) Mental imagery: in search of a theory. Behavioral and Brain Sciences. 25, 157–237.

> Author cites theoretical and experimental research to defend the view that mental imagery is not depictive or pictorial in nature, but rather descriptive or propositional. Suggests that thinking about mental imagery as images in the mind or brain introduces a homunculus problem that must be avoided.

Shepard, R. N. (1984). Ecological constraints on internal representation: Resonant kinematics of perceiving, imagining, thinking, and dreaming. *Psychological Review, 91*(4), 417-447.

> Author elaborates a resonance metaphor for mental imagery (and other internally generated representations) based on an extension of the ecological approach to perception. Suggests that the brain comes to internalize and resonate with the physical constraints that structure the environment, and that imagery can be thought of as a partial, internally generated resonance with these environmental constraints.

Thomas, N. J. T. (1999). Are theories of imagery theories of imagination? An active perception approach to conscious mental content. *Cognitive Science, 23*(2), 207–245.

> Author compares and contrasts quasi-pictorial, descriptive, and active perception accounts of mental imagery. The active perception approach claims that to imagine something, we go through (some of) the same exploratory perceptual behaviors that we would go through if we were actually looking at that thing, even though the thing is not present. Concludes that the active perception account avoids many pitfalls that the other two approaches run into.

## VISUAL IMAGERY

When people are asked to answer the question "what shape are a duck's feet?" they might report *visualizing* those particular effectors in their mind's eye. This is known as "visual imagery." An embodied approach to visual imagery suggests that when we imagine an object we rely on the same perceptual mechanisms that would be engaged if we were actually looking at that object. Kosslyn 1980 and Shepard & Cooper 1982 provide thorough summaries of the early behavioral work on mental imagery, suggesting that mental images are represented in a quasi-pictorial format and that transforming mental images is an analog process, much like transforming actual objects in the world. Shepard & Metzler 1971 is one of the key early findings of this analog process in the context of mental rotation. Spivey & Geng 2001 provides evidence that people make similar eye movements when they imagine or recollect something as when they actually visually explore that thing. Further, Winawer et al. 2010 shows that visual imagery is sufficient to adapt direction-selective neural populations, while O'Craven & Kanwisher 2000 demonstrates that imagining faces and places selectively activates perceptual brain regions that respond to those specific stimuli. Kosslyn et al. 2001 reviews the evidence that mental imagery is supported by the same neural systems that support perception. Pylyshyn 2001 is a critical look the idea that there are really image-like representations in the brain.

Kosslyn, S. M. (1980). *Image and mind*. Cambridge: Harvard University Press.

Author reviews empirical evidence to defend the theory that mental images are represented in a quasi-pictorial or depictive format and that they form a key component of thinking and problem solving.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews. Neuroscience, 2,* 635–642.

Authors review the cognitive neuroscience evidence that mental imagery is supported by perceptual brain regions, and imagery modulates neural activity in a manner analogous to actual perception.

O'Craven, K., & Kanwisher, N. (2000). Mental imagery of faces and places activates corresponding stimulus-specific brain regions. *Journal of Cognitive Neuroscience, 12*, 1013–1023.

Authors conducted a functional MRI experiment where participants looked at images of, and imagined faces and places. Results indicate that the same the neural regions in visual cortex that selectively respond to the perception of faces and places also selectively respond (in an attenuated fashion) to imagining faces and places.

Pylyshyn, Z. (2001). Return of the mental image: Are there really pictures in the brain? *Trends in Cognitive Sciences, 7*(3), 113-118.

Author takes a critical look at the theory that visual imagery is supported by depictive representations in the brain, using both theoretical and experimental research to back up his claims to the contrary.

Shepard, R. N., & Cooper, L. (1982). *Mental images and their transformations.* Cambridge: MIT Press.

Authors review the early literature on mental imagery with an emphasis on the ability to transform those images in an analog fashion.

Shepard, R. N. & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, 171(972). 701-3.

In this experiment, participants were presented with two images of three-dimensional block objects and had to indicate whether the objects were identical or were mirror-images of one another. Response times were linearly proportional to the angular disparity between the objects, suggesting that participants were mentally rotating the objects in order to solve the task.

Spivey, M. J., & Geng, J. J. (2001). Oculomotor mechanisms activated by imagery and memory: eye movements to absent objects. *Psychological Research*, 65, 235- 241.

Authors conducted two experiments where they tracked the eye movements of participants who were asked to imagine or recollect various items. Eye movements were consistent with the actual viewing of those items.

Winawer, J., Huk, A., & Boroditsky, L. (2010). A motion aftereffect from visual imagery of motion. *Cognition, 114*, 276–284.

In this study, participants imagined moving gratings, which led to a measurable motion after-effect in much the same way that actually seeing moving gratings would (albeit in an attenuated fashion). Results support the idea that visual mental imagery is sufficient to adapt direction-selective neurons in visual cortex.

## MOTOR IMAGERY

Take a moment, close your eyes, and imagine shooting a basketball, jogging to your car, or clenching your fist. The ability to mentally simulate a motor action is known as motor imagery. An embodied approach to motor imagery suggests that when we imagine executing an action we rely on the same mechanisms we would engage if we were to actually execute that action. Parsons 1987 and Kunz et al. 2009 provide behavioral evidence that imagining an action is constrained by the same sorts of physiological factors that constrain actual actions. Decety et al. 1991 and Driskell et al. 1994 provide further evidence that imagined actions lead to many of the same physiological consequences as actual actions, including changes in autonomic states and practice effects. Decety 1996, Jeannerod 1994, and Jeannerod & Frak 1999 review the evidence in support of the view that motor imagery is supported by the same neural systems that support motor planning and execution. Finally, van Rooij et al. 2002 demonstrates that motor imagery effects can be predicted and explained by a dynamical systems model that does not assume traditional ideas of mental representation.

Decety, J. (1996). Do imagined and executed actions share the same neural substrate? *Cognitive Brain Research, 3*, 87-93.

Author reviews the functional correlates of motor imagery, using mental chronometry, monitoring autonomic responses and measuring cerebral blood flow in humans. The timing of mentally simulated actions closely mimics actual movement times, while autonomic responses during motor imagery parallel the autonomic responses to actual exercise. Cerebral blood flow increases are observed in the motor cortices involved in the programming of actual movements.

Decety, J., Jeannerod, M., Germain, M., & Pastene, J. (1991). Vegetative response during imagined movement is proportional to mental effort. *Behavioral Brain Research,* 42, 1-5.

In this study, authors measured cardiac and respiratory responses of participants who imagined locomoting at various speeds. These physiological responses increased with increased imagined locomotion speed, though not as much as when participants were actually moving at those speeds.

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79*(4), 481-492.

Authors describe a meta-analysis of the literature on mental practice. Results indicate that mental practice significantly improved performance, though the effectiveness of mental practice was moderated by the type of task, the retention interval between practice and performance, and the length or duration of the mental practice intervention.

Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. *Behavioral Brain Sciences, 17,* 187-245.

> Author conducts an extensive review of the literature on the neural correlates of motor planning and imagery, finding close parallels between the two.

Jeannerod, M, & Frak, V. (1999). Mental imaging of motor activity in humans. *Current Opinion in Neurobiology. 9*(6), 735-9.

> Authors briefly review the cognitive neuroscience literature on motor imagery, concluding that it is supported by the same systems that support motor planning in the brain, and that motor imagery may underlie the perception of tools and other graspable objects, as well as the ability to understand the actions of others.

Kunz, B. R., Creem-Regehr, S. H., & Thompson, W. B. (2009). Evidence for motor simulation in imagined locomotion. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 1458–1471.

> Authors conducted a series of experiments to investigate the role of the motor system in imagined locomotion. Results indicated a strong relationship between imagined walking performance and the biomechanical information available during actual walking.

Parsons, L. M. (1987). Imagined spatial transformations of one's hands and feet. *Cognitive Psychology, 19,* 178–241.

> Author describes an experiment in which participants had to indicate whether an image of a hand or foot on the screen was a left or right limb. The time it took to identify limb laterality was directly proportional to the time it would take, and how difficult it would be, for the participants to rotate their own hand or foot into that position.

van Rooij, I., R. Bongers, and W. Haselager (2002). A non representational approach to imagined action. *Cognitive Science, 26*, 345 375.

> Authors used a non-representational, dynamical systems model to capture behavior in a motor imagery task where participants had to imagine whether or not it would be possible to reach a target while holding a rod of a particular length. Demonstrates that it is not necessary to posit rich internal representations in order to account for motor imagery behavior.

## SOCIAL PERCEPTION

Human beings are social animals deeply embedded in richly structured cultural worlds. Successful navigation of our social environment requires that we perceive and understand the actions, intentions and emotions of the people around us. The traditional approach to action and emotion understanding suggests that we accomplish these feats through a folk psychological "theory of mind," which allows us to represent and reason about the mental life of others in much the same way a scientist might use a theory to understand a complex natural phenomenon. Gordon 1986 introduced an alternative possibility, that folk psychology is instead accomplished via a mental simulation process: to understand another person's actions or intentions we put ourselves in their shoes and imagine ourselves engaging in the same actions. This approach has a decidedly embodied flavor since it relies on sensorimotor processes rather than abstract propositional representations. The nature of folk psychology has become a controversial topic, however, with supporters of theory, simulation, and hybrid views engaged in ongoing debate in the literature. Gopnik & Wellman 1992 offers a well thought-out defense of the theory view, for example. In recent years, evidence from the cognitive neurosciences has been marshaled in support of the embodied simulation view. In the 1990s, researchers discovered neurons in the primate brain that responded both when the monkey performed a specific action and when they observed another agent performing the very same action. Rizzolatti & Craighero 2004 offers a thorough review of these “mirror neurons” in both the primate and human brain, while Gallese & Goldman 1998 defends the view that these neurons support the simulation theory of folk psychology. More recently, Gallese et al. 2004 and Niedenthal et al. 2005 have suggested that this embodied approach can offer a natural, unifying theoretical framework for understanding social perception and social cognition more generally.

Gallese, V., & Goldman, A (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences, 2*, 493-501.

> Authors defend the view that understanding the behavior and intentions of others is accomplished via mental simulation or resonance rooted in the functioning of a mirror-neuron system that is involved with both perceiving and executing goal-directed actions.

Gallese, V., Keysars, C., & Rizzolatti, G. (2004). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences, 8*(9), 396-402.

> Authors suggest that the ability to understand others’ actions and emotions is supported by the activation of the mirror neuron system and viscero-motor centers that serve a similar function.

Gopnik, A. & Wellman, H. M. (1992). Why the child’s theory of mind really is a theory. *Mind & Language, 7*(1-2), 145-171.

> Authors review empirical and theoretical reasons for claiming that theory of mind abilities are best captured by a theory-theory account, and why simulation accounts are inadequate.

Gordon, R. (1986). Folk Psychology as Simulation. *Mind and Language, 1*: 158–171

> Author introduces and defends the idea that folk psychological abilities are supported by mental simulation rather than a tacit theory of mind.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S. & Ric, F. (2005) Embodiment in attitudes, social perception, and emotion. Personality and Social Psychology Review.

> Authors review the theoretical and empirical work in support of the view that bodily states and embodied simulations of experience in the brain’s sensorimotor networks support social information processing.

Rizzolatti, G. and Craighero, L. (2004). The mirror-neuron system. Annual Review of Neuroscience 27, 169–192.

> Authors review and summarize the research on mirror-neurons; multimodal neurons that are activated both when an agent observes another agent engaging in an action and when an agent actually executes that same action.

## ACTIONS

How do we perceive and understand the actions of the people around us? According to the EC perspective, our ability to perceive actions is at least partially dependent on our ability to actually execute those actions. That is, we understand actions by imagining performing them ourselves. In recent years, a great deal of experimental evidence has been gathered in support of this view. Flanagan & Johansson 2003 shows that participants observing an action make eye movements that are highly similar to the ones they make when they perform the action themselves. Aglioti et al. 2008 demonstrates that motor expertise is correlated with the ability to anticipate the success or failure of an action simply from watching a brief video clip, while Casile & Giese 2006 shows that motor training increases people’s ability to visually discriminate the specific action that they have trained on. Calvo-Merino et al. 2005 provides evidence that motor brain regions are recruited more during action observation when the action being observed is one that the person has experience performing. Several researchers have suggested that it is the mirror neuron system (described in Social Perception) that underlies action understanding in this way. Rizzolatti et al. 2001 and Buccino et al. 2004 offer support for this view. However, this remains a controversial claim in the field, and scholars like Hickok 2009 have argued that mirror neurons cannot explain action understanding in monkeys or humans.

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience, 11*, 1109-1116.

> Elite basketball players, coaches and journalists with a lot of experience watching (but not playing) basketball, and novices observed clips of basketball shots and had to indicate whether the ball was going to go in, miss, or if they were uncertain. Elite players were the best at predicting when the ball would go in. Motor expertise is important in the perceptual anticipation of actions performed by others.

Buccino, G., Binkofski, F., & Riggio, L. (2004). The mirror neuron system and action recognition. *Brain and Language, 89*, 370-376.

> Authors review the literature on mirror neurons in monkey and human brains. Suggest that the evidence supports the view that the mirror neuron system supports action recognition in both species.

Calvo-Merino, B., Glaser, D. E., Grèzes, J., Passingham, J. E., & Haggard, P. (2005). Action observation and acquired motor skills: An fMRI study with expert dancers. *Cerebral Cortex, 15*, 1243-49.

> In this study, experts in ballet, capoeira and inexpert control participants viewed videos of ballet or capoeira actions while undergoing functional magnetic resonance imaging. Results showed greater bilateral activation in motor brain regions when expert dancers viewed movements that they had been trained to perform compared to movements they had not, supporting the view that people understands action via motor simulation, and that motor experience influences this process.

Casile, A. & Giese, M. A. (2006). Nonvisual motor training influences biological motion perception. *Current Biology, 16*, 69-74.

> Visual assessment of point-light walker gait patterns was done before and after non-visual training. During training, participants practiced a novel upper-body movement that matched one of the target gait patterns. After training, they showed selective improvement in their ability to visually discriminate this movement, and performance was correlated with how well they were able to learn and execute the movement. Results show that motor learning can influence visual action perception.

Flanagan, J. R., & Johansson, R. S. (2003). Action plans used in action observation. *Nature, 424*, 769-770.

> Authors investigated the eye movements participants made while observing another agent perform a block standing task. Results showed the eye movements the observer made were similar to the eye movements they made when they performed the task themselves. The coordination between the eye movements and the actor’s hand was predictive, rather than reactive, supporting the idea that action observation is grounded in motor system activity and mental simulation.

Hickok, G. (2009). Eight problems for the mirror neuron theory of action understanding in monkeys and humans. *Journal of Cognitive Neuroscience, 21*(7), 1229-1243.

Author critically reviews the literature suggesting that mirror neurons support action understanding. Suggests that primate data do not currently support this theory because it has never been directly tested in the appropriate manner. Further suggests that human data actually provide a strong case against the mirror neuron theory of action understanding.

Rizzolatti, G., Fogassi, L., and Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience 2*, 661–670.

Authors review the evidence that the mirror neuron system is involved in understanding and imitating the actions of others in monkeys and humans. Support the theory that understanding actions involves mapping the visual information onto the motor plans for executing the observed action.

## EMOTIONS

How do we perceive and understand the emotions of the people around us? According to the EC perspective, our ability to perceive emotions is supported by our ability to actually experience and express those emotions ourselves. Adolphs et al. 2000 suggests that brain damage to specific somatosensory brain regions can selectively impair emotion recognition. Niedenthal et al. 2001 demonstrates that experiencing a specific emotion facilitates the ability to detect when an actor expressing a congruent facial expression changes their expression. Heberlein & Atkinson 2009 offers a broad overview of this literature, including evidence that vocal prosody and whole body cues are additional factors that support this simulation view of emotion recognition. Niedenthal 2007 also provides a review of this field of research, including evidence that these embodied simulation processes also support our ability to think about emotions and understand emotional language. Indeed, Havas et al. 2010 demonstrates that reading a sentence about a particular emotion leads to patterns of activity in facial muscles consistent with that emotion, and that paralyzing specific facial muscles using a Botox injection leads to selective impairments in processing emotional language.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G. & Damasio, A. R. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *Journal of Neuroscience 20*:2683–90.

Authors performed a quantitative analysis of over 100 patients with focal brain damage to assess the role of specific brain regions in emotional expression recognition. Found that recognizing emotions from visually presented facial expressions requires right somatosensory-related cortices, consistent with the idea that emotional state recognition is accomplished by internally generating somatosensory representations that simulate how the other individual would feel when displaying a certain facial expression.

Havas, D. A., Glenberg, A. M., Gutowski, K. A., Lucarelli, M. J., & Davidson, R. J. (2010). Cosmetic use of botulinum toxin-A affects processing of emotional language. *Psychological Science, 21*, 895-900.

Authors used facial electromyography to demonstrate that reading emotional sentences leads to patterns of activity in facial muscles that correspond to the emotions expressed linguistically. Another study demonstrates that patients who have received facial Botox injections for frown lines are selectively impaired at processing angry and sad (but not happy) sentences. Findings suggest that facial movements mediate a bi-directional link between emotion and language.

Heberlein, A. S., & Atkinson, A. P. (2009). Neuroscientific evidence for simulation and shared substrates in emotion recognition: Beyond faces. *Emotion Review, 1*(2), 162–177.

Authors review evidence for simulation-based theories of emotion recognition, including evidence that vocal prosody and whole body cues, in addition to facial expressions, are implicated in emotion recognition and understanding.

Niedenthal, P. M. (2007). Embodying emotion. *Science,* 316, 1002-5.

Author provides an overview and summary of the idea that perceiving emotions, thinking about emotions, and comprehending emotional language all involve perceptual, somatovisceral, and motoric re-experiencing of the relevant emotion in oneself.

Niedenthal, P. M., Brauer, M., Halberstadt, J. B. & Innes-Ker, A. H. (2001) When did her smile drop? Facial mimicry and the influences of emotional state on the detection of change in emotional expression. *Cognition and Emotion 15*: 853–64.

In this study, participants in manipulated emotional states had to indicate changes in emotional facial expressions of actors in computerized movies. Results demonstrated that participants were faster to detect changes in facial expressions that matched their own manipulated state. Supports the role of facial mimicry in perception of emotional expression.

## LANGUAGE, CONCEPTS AND MEANING

What is the nature of language, conceptual knowledge, and other high-level cognitive phenomena that seem to lie at the core of human mental life? Classical approaches to these topics treat concepts as discrete, amodal units in a symbolic language of thought, where thinking amounts to formal, syntactic transformations over these symbols. On this view, concepts are represented outside of sensorimotor systems in the brain. Understanding language amounts to translating incoming speech signals into the symbolic language of thought according to particular syntactic rules. This approach is famously associated with Fodor 1975, but it remains a popular view throughout the cognitive sciences. One major challenge for this approach is to understand how concepts could possibly be learned or acquire meaning. The issue of semantic grounding was critically examined by Harnad 1990, which suggests that abstract, symbolic representations must be grounded in lower level perceptual and categorical representations. More recently, proponents of EC have suggested that concepts are not represented as amodal symbols, but rather as patterns of activity in modality-specific perceptual and motor brain regions. On this view, for example, thinking about the concept of a car involves re-instantiating the patterns of neural activation in (a) visual brain areas that represent the visual properties of a car, (b) auditory brain areas that represent the sounds of cars, (c) motor brain areas that represent the action of steering a wheel, and so on. This view of conceptual knowledge is very much tied to embodied accounts of mental imagery (as described in Mental Imagery). Barsalou 1999 offers a detailed, thorough account of this perspective, while Gallese & Lakoff 2005 provides a more concise review of same basic idea while demonstrating how this framework can be extended to account for sensorimotor representations of abstract concepts via metaphorical mapping. According to embodied accounts, understanding language involves a mental simulation of the events being described, instantiated in the sensorimotor system. Fischer & Zwaan 2008 offers a broad overview of the empirical evidence in support of this hypothesis. Finally, embodied approaches view communication not as a simple transmission of symbols from one person to another, but as a species of joint action that is situated in a real-world context and unfolds dynamically over time, as described by Clark 1996.

Barsalou, L. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences* 22, 577–660.
Author reviews and defends the view that conceptual knowledge is represented in modality-specific perceptual and motor brain regions, and that thinking involves re-instantiating the neural activation in these systems that would be engaged if one were experiencing a particular item or event. Suggests that this perceptual symbol systems view can account for many of the appealing features of traditional amodal symbol systems views while overcoming their deficiencies.

Clark, H. H. (1996). *Using language*. Cambridge University Press.
Author describes language and communication not as a process of information transfer, but rather as a situated, coordinated joint action much like dancing a waltz. Book provides an overview of the theoretical and empirical support for this dynamic view of language use.

Fischer, M. H. & Zwaan, R. A. (2008). Embodied language: A review of the role of the motor system in language comprehension. *Quarterly Journal of Experimental Psychology, 61*(6), 825- 850.
Authors provide a broad review of the evidence in support of the idea that comprehending verbal descriptions of actions involves a mental simulation of the described scenario instantiated in the sensorimotor systems of the brain.

Fodor, J. (1975). *The Language of Thought.* Cambridge, MA: Harvard University Press.
Author suggests that concepts are represented as amodal symbols in the mind, and that thinking amounts to algorithmic or syntactic transformations over these symbols. Work represents a classical, traditional approach to knowledge and thinking in cognitive science.

Gallese, V. & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology, 21*(0), 1-25.
Authors argue against traditional amodal symbol system view of concepts and defend the idea that both concrete and abstract concepts can be supported by sensorimotor systems in the brain.

Harnad, S. (1990). The symbol grounding problem. Physica D, 42, 335-346.
Author suggests that purely symbolic, abstract models of the mind cannot account for the semantic content of mental life. Suggests that "symbolic representations" must be grounded in bottom-up, non-symbolic representations, including "iconic representations," which are akin to perceptual representations, and "categorical representations," which are feature detectors that pick out invariant features of object and event categories from their sensory projections.

## SPEECH PERCEPTION

The traditional, dominant approach to speech perception assumes that processing speech signals is largely an auditory problem; perceiving and producing speech are presumed to be handled by separate systems. For the last half-century, however, Alvin Liberman and his colleagues have offered an alternative view that suggests that the same system involved with producing speech is also recruited to process incoming speech signals. On this view, speech perception is thought of as a particular kind of gesture perception, and these speech gestures are understood by identifying (and covertly activating) the underlying motor commands that would be used to generate those sounds. Liberman et al. 1967 is one of the earliest presentations of this hypothesis, while Liberman & Mattingly 1985 offers an updated, revised version of theory to account for a wider range of empirical findings. Evidence for this theory comes in a variety of forms. For example, Fadiga et al. 2002 demonstrates that there is an increase in motor-evoked potentials in the tongue when people listen to words that would require strong tongue movements to produce. Though the original theory posited that speech perception was implemented in a specialized module, Gallantucci et al. 2006 and others have recently suggested that it may simply be another form of a more general action perception, as described in Action. Thus, from an EC perspective, perceiving speech involves embodied motor simulation or resonance. However, Massaro & Chen 2008 suggests that the evidence in favor of the motor theory is dubious at best, and that more traditional accounts better capture the empirical data.

Fadiga, L., Craighero, L., Buccino, G., & Rizzolatti, G. (2002). Speech listening specifically modulates the excitability of tongue muscles: a TMS study. *European Journal of Neuroscience, 15*, 399-402.

Authors use transcranial magnetic stimulation (TMS) to demonstrate that when participants listen to speech, there is an increase of motor-evoked potentials recorded from the listeners' tongue muscles when the words they are hearing strongly require tongue movements to pronounce.

Gallantucci, B., Fowler, C., & Turvey, M. T. (2006). The motor theory of speech perception reviewed. *Pyschonomic Bulletin & Review, 13,* 361-377.

Authors review the evidence in favor of the motor theory of speech perception, evaluating the claims that speech processing is special, that perceiving speech is akin to perceiving gesture, and that the motor system is recruited to perceive speech. They find support for the latter two claims, but not the first, concluding instead that speech perception is better understood to be another component of action perception in general.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P. & M. Studdert- Kennedy. (1967). Perception of the speech code. *Psychological Review, 74*, 431-461.

Authors introduce the motor theory of speech perception. Suggest perceiving phonemes poses a special problem, and that one solution might be to use the invariant neuro-motor commands that project to the articulatory muscles involved in speech production in speech perception as well.

Liberman, A. M. & Mattingly, I. G. (1985). The motor theory of speech perception revised. *Cognition, 21*, 1-36.

Authors update Liberman's original motor theory of speech perception to accommodate more empirical findings. Suggest that phonetic information is perceived by a dedicated module specialized to detect the intended gestures of the speaker. Speech production is also implemented by this system, which highlights the fact that this is a motoric theory, rather than a purely auditory theory of speech processing.

Massaro, D. W. & Chen, T. H. (2008). The motor theory of speech perception revisited. *Psychonomic Bulletin & Review, 15*(2), 453-457.

Authors argue against the view that speech perception involves the motor system and is akin to perceiving gesture or action. Instead, they suggest that a prototypical pattern recognition model can more easily and simply capture the relevant data, and that the evidence in favor of the motor theory of speech perception is interpretable from a variety of theoretical perspectives at best.

## CONCRETE CONCEPTS

How do we think about the objects, actions and events that we experience in our daily lives? Traditional approaches to this question suggest that concepts are represented as abstract, amodal symbols in a language of thought ("mentalese"), and that thinking amounts to algorithmic transformations over these symbols. Alternatively, EC approaches suggest that conceptual knowledge is grounded in modality-specific sensorimotor systems in the brain, and that thinking consists of a mental simulation of these events. Barsalou et al. 2003 offers a concise review of this approach, drawing on theoretical and experimental research to suggest that thinking about a car, for example, involves the re-instantiation of the same neural patterns associated with actually experiencing a car (this is a version of the *perceptual symbol system* theory articulated by Barsalou 1999, cited in Language, concepts and meaning). Martin 2007 reviews the neuroscientific evidence in support of the view that object concepts are stored in the same sensorimotor systems that were active when the concept was acquired. Stanfield & Zwaan 2001, Zwaan et al. 2002, and Richter & Zwaan 2009 all demonstrate experimentally that reading words and sentences reliably activates specific perceptual representations related to orientation, shape, and color. Hauk et al. 2004 and Pulvermüller et al. 2005 provide experimental evidence that understanding action words like *kick* involves selective activation of motor brain regions dedicated to those specific effectors (in this case, the foot motor area). Glenberg & Kaschak 2002 further shows that understanding action sentences (e.g. "close the drawer") involves motor simulation and can affect actual motor movements. However, Markman & Brendl 2005 suggests that these effects are also mediated by people's abstract representations of where they are located in space, rather than simply their current, embodied physical location.

Barsalou, L. W. Simmons, W. K., Barbey, A. K., & Wilson, C. D. (2003). Grounding conceptual knowledge in modality-specific systems. *Trends in Cognitive Science, 7*(2), 84-90.

> This concise review article summarizes the evidence that conceptual knowledge is supported by modality-specific systems in the brain that support perception, action, and emotion. Defends the view that thinking about an object or action involves a mental simulation of that object or action comprised of re-instantiation of the neural activation that accompanies actually experiencing that object or action.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action*. Psychonomic Bulletin & Review, 9*, 558–565.

> Authors describe the action-sentence compatibility effect associated with language processing. In the study, participants made sensibility judgments about sentences (e.g. "close the drawer") by making a response toward or away from the body. Responses were faster when the response action matched the implied direction of the sentence. Results also obtained for abstract sentences (e.g. "Liz told you the story").

Hauk, O., Johnsrude, I & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex*. Neuron, 41*, 301 – 307

> Authors use an event-related functional MRI design to demonstrate that reading action words such as lick and kick leads to activation in effector-specific regions of the motor strip in the brain. Support the view that understanding action words involves mental simulation of those actions.

Markman, A.B., & Brendl, C.M. (2005). Constraining theories of embodied cognition. *Psychological Science, 16*(1), 6-10.

> Authors revisit a movement-compatibility effect experiment in which people are faster to respond to positive words by pulling a lever than by pushing a lever (and vice versa for negative words). Show that the effect depends on people's representation of their selves in space rather than on their physical location. Suggest that accounting for embodied phenomena requires understanding the interplay between sensorimotor representations and people's representations of their selves in space.

Martin, A. (2007). The representation of object concepts in the brain. *Annual Review of Psychology, 58*, 25-45.

Author reviews relevant literature to support the claim that information about salient properties of an object (what it looks like, how it moves, how it is used) is stored in sensory and motor systems active when that information was acquired. As a result, object concepts belonging to different categories like animals and tools may be represented in partially distinct sensorimotor networks.

Pulvermüller, F., Hauk, O., Nikulin, V.V., & Ilmoniemi, R.J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience, 21*, 793 – 797.

In this experiment, participants performed a lexical decision task while undergoing transcranial magnetic stimulation (TMS) to different areas of the motor strip in the left hemisphere. TMS to hand motor area led to faster responses to hand words, and TMS to foot motor area led to faster responses to foot words. Results show that the left hemispheric cortical systems for language and action are linked in a category-specific manner.

Richter, T. & Zwaan, R.A. (2009). Processing of color words activates color representations. *Cognition,* 111, 383-389

In a lexical decision task, participants were faster to judge the sensibility of color words when they were preceded by a matching color. In a color discrimination task, participants were slower to respond when the trial was preceded by an incongruent color word, even when no task had to be performed on those words. Authors conclude that understanding color words and perceiving colors draw on overlapping representational resources.

Stanfield, R.A. & Zwaan, R.A. (2001). The effect of implied orientation derived from verbal context on picture recognition. *Psychological Science*, 12, 153-156.

In this experiment, participants read a sentence that implied either a vertical or horizontal spatial orientation of an object (e.g. “Jon put the pencil in the cup” implies vertical), and then indicated whether an object in a picture was mentioned in the sentence or not. Participants were faster to respond to the picture when the orientation of the object in the picture matched the implied orientation of the sentence.

Zwaan, R.A., Stanfield, R.A., & Yaxley, R.H. (2002). Language comprehenders mentally represent the shapes of objects. *Psychological Science*, 13, 168-171.

In this study, participants read sentences that described an object in a certain location that implied a specific shape (e.g. an egg in the refrigerator vs. skillet). They then saw a picture of an object and had to name it or say whether it had appeared in the previous sentence. Responses were fastest when the shape of the object in the picture matched the shape implied by the sentence.

## ABSTRACT CONCEPTS

How do we reason about abstract concepts like time, crime, ideas, and the mind? This question seems to pose a unique challenge to embodied views of language and thought, since these abstract things cannot be directly experienced through the senses in the same way that colors and actions can be experienced. Lakoff & Johnson 1980 introduced the theory of conceptual metaphor to help address this issue. They observed that natural language is exceedingly figurative: when people talk about complex or abstract topics, they rely a great deal on systems of metaphors, borrowing words and phrases from other, more concrete domains. For example, to talk about theories, people often rely on building metaphors (theories must have a *solid foundation* and be *well-supported* by the data or they might *fall apart*). Therefore, this theory claims that people understand and reason about abstract domains via metaphorical extension from embodied experiences with more concrete domains. Lakoff and Johnson 1999 attempts to use this account to examine and deconstruct the history of western philosophy, and to replace it with a philosophical system grounded in the view from EC. Lakoff and Núñez 2000 attempts to understand how abstract systems of mathematics may also be grounded in embodied experience in a similar fashion. This theory has not been without its detractors, however. Murphy 1996 offers a compelling argument against metaphoric conceptual representation, drawing on both theoretical and empirical research. More recently, researchers have begun to test these ideas experimentally, often by investigating whether experience in a concrete domain can influence thinking or reasoning in the abstract domain that metaphorically maps to it. Casasanto & Boroditsky 2008 demonstrates that spatial extension can influence judgments of temporal extension, Jostmann et al. 2009 shows that physical weight can influence judgments of importance, and Ackerman et al. 2010 shows that various physical touch experiences can influence different interpersonal impressions and decisions. Glenberg et al. 2008 shows that processing abstract (and concrete) language modulates motor system activity, suggesting that these effects are grounded in sensorimotor systems.

Ackerman, J., Nocera, C., and Bargh, J. (2010). Incidental Haptic Sensations Influence Social Judgments and Decisions. *Science* 328, 1712.

> Authors suggest that touch experience may serve as physical grounding for interpersonal conceptual and metaphorical knowledge. A series of experiments demonstrates that priming participants by having them hold heavy or light clipboards, touch rough or smooth puzzles, and touch hard or soft objects influences impressions and decisions formed about other people and situations in a metaphor-congruent manner (e.g. touching a hard object leads to increased rigidity in negotiations).

Casasanto, D. and Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition* 106, 579–593.

> Across several experiments, authors found that the length (in spatial extension) of a line on a computer screen affected how long (in temporal duration) it was judged to remain on the screen: the longer the line, the longer the time. Supports the view that people think about time using spatial representations, even in a non-linguistic task.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., Buccino, G. (2008). Processing abstract language modulates motor system activity. *Quarterly Journal of Experimental Psychology, 61*, 905-919.

> In two experiments, participants responded to concrete and abstract motion transfer sentences (and control sentences) by making a response toward or away from their bodies. Congruency effects were observed, and transcranial magnetic stimulation showed that both types of sentences led to greater changes in hand muscle activity relative to control sentences.

Jostmann, N. B., Lakens, D., and Schubert, T. W. (2009). Weight as an embodiment of importance. *Psychological Science* 20, 1169–1174.

> Authors suggest that the abstract concept of importance is grounded in the bodily experience of weight, as implied by the metaphors we use in language (e.g. important ideas carry a lot of *weight*). Holding a heavy versus light clipboard led to increased judgments of importance (judging monetary value and fair decision-making procedures) and caused more elaborate thinking and greater polarization of agreement ratings for strong versus weak arguments.

Lakoff, G. and Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.
Authors' seminal work on the metaphorical structure of language and thought. The way we talk about abstract topics often involves using language borrowed from more concrete domains, and this is a pervasive feature of natural language. Suggest that we reason about abstract ideas via these metaphorical mappings.

Lakoff, G. and Johnson, M. (1999). *Philosophy in the Flesh: The Embodied Mind and its Challenge to Western Thought*. New York, NY: Basic Books.
Presents the authors theory that the mind is inherently embodied, that thinking is mostly unconscious, and that abstract concepts are largely metaphorical. Authors use this framework to explain how we think about traditional philosophical concepts such as the mind, self, and causation, and then apply this approach to deconstruct the philosophical views of a wide range of Western philosophers.

Lakoff, G., & Núñez, R. (2000). *Where mathematics comes from*. New York: Basic Books.
Authors argue that even the most abstract mathematical abilities emerge from the basic metaphorical structure of the human conceptual system that itself emerges from embodied experience.

Murphy, G. L. (1996). On metaphoric representation. *Cognition 60*, 173–204.
Author provides both empirical and theoretical arguments against the view that concepts, including abstract concepts, are structured metaphorically,

## GESTURE

Human beings naturally and spontaneously gesture with their hands when they speak. Traditionally, gesture was viewed as a non-verbal accessory to communication at best, and a mere epiphenomenon at worst. However, many researchers now view gesture as an important (and literally embodied) component of language, reasoning (especially spatial reasoning), learning, and memory. David McNeill and Susan Goldin-Meadow are widely recognized as the leaders in the field of gesture research, and McNeill 2005 and Goldin-Meadow 2003 serve as in-depth overviews of the empirical and theoretical work that views gesture as integral to human thought processes. Hostetter & Alibali 2008 defends a theory of gesture as simulated action to explain how gesture may arise from an EC perspective. Goldin-Meadow and Beilock 2010 offers a similar view, suggesting that gestures do not merely reflect a person's thoughts, but that they can also feed back to impact the thought process itself. Cook et al. 2008 provides experimental evidence that gesture can positively affect learning, while Goldin-Meadow et al. 2001 provides experimental evidence that gesturing can lighten cognitive load, thereby enhancing working memory abilities.

Cook, S. W., Mitchell, Z., & Goldin-Meadow, S. (2008). Gesture makes learning last. *Cognition*, 106, 1047 - 1058.
In this experiment, the authors manipulated children's gesturing during a mathematical concept-learning task. Children retained more knowledge about what they had learned when they were required to gesture during instruction, compared to when they were required to speak (and not gesture). Authors suggest that gesture allows children to represent certain concepts in an alternative, embodied format.

Goldin-Meadow, S. (2003). *Hearing gesture: How our hands help us think.* Cambridge, MA: Harvard University Press.

> Author reviews the empirical and theoretical support for the view that gesture is deeply involved in language and thought processes, is thus much more than mere hand waving.

Goldin-Meadow, S., Nusbaum, H., Kelly, S., & Wagner, S. (2001). Explaining math: Gesturing lightens the load. *Psychological Science, 12*, 516-522.

> In this experiment, adults and children had to remember a list of letters or words while explaining how they solved a math problem. Both groups remembered more items when they gestured while explaining, suggesting that gesturing can lighten cognitive load and help enhance certain memory processes.

Goldin-Meadow, S. & Beilock, S. L. (2010). Action's influence on thought: The case of gesture. *Perspectives in Psychological Science, 5*, 664-674.

> Authors review the research on how both action and gesture can influence thought, bringing these two literatures together to argue that gestures: (a) contain detailed perceptual-motor information about the actions they represent, and (b) do not merely reflect thoughts, but also feed back and alter thought processes. Conclude that gesture may be a unique bridge between action and abstract thought.

Hostetter, A. B. & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review, 15*(3), 495-514.

> Authors argue that gestures emerge from perceptual and motor simulations that underlie embodied language and mental imagery processes. They propose a gestures-as-simulated-action framework to account for this view.

McNeill, D. (2005). *Gesture and Thought*. Chicago, IL: University of Chicago Press.

> Author reviews a great deal of empirical and theoretical work on gesture, supporting the view that gesture fuels thought and speech. Suggests that language is inseparable from imagery, language, and cognition. Situates this study in the theoretical and research tradition of Vygotsky.

## MORAL REASONING

Traditionally, moral reasoning has been viewed as an abstract, rational cognitive process. However, researchers have recently suggested that reasoning about moral issues may be grounded in certain physiological states of the body, including emotions such as disgust and anger. Rozin et al. 1999 provides theoretical and empirical evidence that different types of moral transgressions are reliably associated with different emotional responses cross-culturally. Disgust in particular has been identified as a crucial emotion that underlies moral reasoning, as described by Haidt et al. 1997. This possibility is suggested by common metaphors used to discuss moral issues (e.g., a moral transgression may *disgust* you or *leave a bad taste in your mouth*, so in order to feel *pure* you would have to *wash away your sins*). On this view, feelings of disgust are deeply associated with moral transgression and are used to guide reasoning about the moral valence of events. Schnall et al. 2008 demonstrates that inducing feelings of disgust leads to more severe moral judgments, while Zhong & Liljenquist 2006 and Schnall et al. 2006 show that physical cleanliness can reduce the severity of moral judgments as well as feelings of threat associated with moral self-image. Chapman et al. 2009 demonstrates that the facial expressions elicited by gustatory distaste and basic disgust are very similar to those elicited by moral disgust, while Borg et al.

2008 reveals that the neural correlates of pathogen-related and moral disgust are similar as well. Taken together, these findings suggest that moral reasoning may be grounded in emotional systems.

Borg, J. S., Lieberman, D., & Kiehl, K. A. (2008). Infection, incest, and iniquity: Investigating the neural correlates of disgust and morality. *Journal of Cognitive Neuroscience, 20*(9), 1529-1546.

> Authors conducted a functional MRI experiment to isolate the neural correlates of disgust as elicited by pathogen-related and moral stimuli. Conclude that many of the same neural structures underlie both forms of disgust, but also that neither disgust nor morality are simple, unified psychological or neurological phenomena.

Chapman, H. A., Kim, D. A., Susskind, J. M., & Anderson, A. K. (2009). In bad taste: Evidence for the oral origins of moral disgust. *Science, 323,* 1222-6.

> Authors found similar facial motor activity evoked by gustatory distaste (tasting something unpleasant), basic disgust (looking at a picture of a contaminant), and moral disgust (unfair treatment in an economic game).

Haidt, J., Rozin, P., McCauley, C., & Imada, S. (1997). Body, psyche, and culture: The relationship of disgust to morality. *Psychology and Developing Societies, 9*, 107-131.

> Authors offer a thorough overview of the emotion of disgust and summarize the early research linking disgust to moral reasoning across different cultures.

Rozin, P., Lowery, L., Imada, S., & Haidt, J. (1999) The moral-emotion triad hypothesis: A mapping between three moral emotions (contempt, anger, disgust) and three moral ethics (community, autonomy, divinity*). Journal of Personality and Social Psychology, 76*, 574-586.

> Authors propose that emotions of contempt, anger, and disgust are typical responses to different types of moral code violations (of community, individual rights, and sanctity, respectively). Used a cross-cultural study design to find support for this hypothesis in American and Japanese students by having them assign an appropriate facial expression or word to different moral violation scenarios, and measuring the facial expressions of the Americans.

Schnall, S., Benton, J., & Harvey, S. (2006). With a clean consciences: Cleanliness reduces the severity of moral judgments. *Psychological Science, 19*(12), 1219-1222.

> Authors conducted two experiments to demonstrate the role the experience of cleanliness plays in moral decision-making. Activating the concept of cleanliness and actually physically cleaning oneself were shown to reduce the severity of moral transgression judgments compared to a control group.

Schnall, S., Haidt, J., Clore, G., & Jordan, A. (2008). Disgust as embodied moral judgment. *Personality and Social Psychology Bulletin, 34,* 1096-1109.

> Participants made moral judgments while experiencing extraneous feelings of disgust by being exposed to a bad smell, working in a dirty room, recalling a disgusting experience, or watching a disgusting video. Feelings of disgust led to more severe moral judgments (compared to, e.g., feelings of sadness), and three of the experiments found that this effect was influenced by participants' sensitivity to their own bodily sensations.

.

Zhong, C., & Liljenquist, K. (2006). Washing away your sins: Threatened morality and physical cleansing. *Science, 313,* 1451-2.

Authors highlight physical cleansing as a focal element in religious ceremonies and suggest that bodily purity may be deeply associated with moral purity. In three experiments they demonstrate that a threat to one's moral purity leads to a greater mental accessibility of cleansing-related concepts, a greater desire for cleansing products, and a greater likelihood of taking antiseptic wipes. Physical cleansing is shown to reduce threats to one's moral self-image.

## DISTRIBUTED, SITUATED AND EXTENDED COGNITION

Traditional accounts of cognition place the mind solely within the confines of the skull: the mind *is* what the brain *does*. However, proponents of EC have suggested that a complete description of the mind must include features of the environment as well. For example, Hutchins 1995a suggests that a pilot and the cockpit they are situated in can be fruitfully analyzed as comprising a singular cognitive system. Cognitive processes can also be distributed across several individuals working in concert, as described by Hutchings 1995b in the case of navigation. People also manipulate features of their environment in order to simplify cognitive tasks and facilitate problem solving, as described by Kirsh 1995 and Kirsh & Maglio 1994. Spivey et al. 2004 summarizes much of the research on this topic, and suggests that eye movements and fixations can be thought of as the cognitive liaisons that mediate between external and internal representations. The idea that the mind is extended beyond the individual agent (also known as *externalism*) has become a hot topic in the philosophy of mind, especially since the publication of Clark & Chalmers 1998, which defends this extended mind hypothesis. Adams & Aizawa 2008 provides a philosophical opposition to this view, claiming that cognitive agents may be coupled to their environment without the environment being constitutive of cognitive processes. Menary 2010 is a collection of essays, mostly from a philosophical perspective, that explore both sides of this debate.

Adams, F. & Aizawa, K. (2008). *The Bounds of Cognition*. Wiley-Blackwell.

Authors critically examine, and ultimately reject the extended mind hypothesis (externalism) that has been put forth by other scholars. Conclude that while cognitive systems may be coupled with their environment, it would be a fallacy to claim that the environment itself is partially constitutive of the cognitive system itself.

Clark, A. & Chalmers, D. (1998) The extended mind. *Analysis 58*(1):7–19.

Authors explore the idea that the mind of an agent is not located solely within the confines of the skull, but rather may be thought of as literally extending into the environment. For example, humans offload cognitive processes (e.g. memory) onto the environment in such a way that a complete description of the cognitive system should include features of the world (e.g. through the use of written notes).

Hutchins E. (1995a). How A Cockpit Remembers its Speeds. *Cognitive Science, 19*, 265-288.

Author analyzes the ways in which a pilot and the cockpit they are situated in can be understood as the functioning of a single, distributed cognitive system that encompasses the dynamic interaction between agent and environment. Concludes that systems that are larger than an individual may have cognitive properties in their own right that cannot be reduced to the cognitive properties of the agent in isolation.

Hutchins, E. (1995b). *Cognition in the Wild.* Cambridge, MA: MIT Press.

Author explores the ways in which a cognitive process can be seen as distributed across many individuals engaged in a particular set of culturally conditioned practices. Using boat navigation as his principle example, and comparing Western and Micronesian navigation practices, Hutchins convincingly demonstrates that cognition is a situated activity and that cognitive processes can extend beyond the mind if the individual agent.

Kirsh, D. (1995). The intelligent use of space. *Artificial Intelligence, 73*, 31-68.

Author explores the ways in which people organize and manage the space around them in order to facilitate various behaviors and cognitive processes. Emphasizes the situated, embodied constraints in behavior and how workspace management can overcome some of these constraints by simplifying perceptual, choice, and internal computational processes.

Kirsh, D. & Maglio, P. (1994). On Distinguishing Epistemic from Pragmatic Actions. *Cognitive Science, 18*(4), 513-549.

Authors use evidence from Tetris to demonstrate that people actively modify their environments (i.e. rotate Tetris pieces in the game itself rather than in their minds only) in order to simplify and facilitate task performance. This epistemic action, which is performed to uncover information that is hidden or hard to compute mentally, is distinguished from pragmatic actions, which are performed to bring a person closer to a goal state.

Menary, R. (ed.) (2010). *The Extended Mind*, Cambridge, MA: MIT Press.

Collection of essays written by both supporters and opponents of the extended mind hypothesis, mostly from a philosophical perspective.

Spivey, M., Richardson, D.C., & Fitneva, S. (2004). Thinking outside the brain: Spatial indices to linguistic and visual information. In J. Henderson and F. Ferreira (Eds.), *The Interface of Vision, Language and Action*. New York: Psychology Press.

Authors review the empirical evidence in favor of the view that a full description of vision (and higher-level cognitive behaviors) must include the structure of the environment itself. Eye movements and fixations are understood to serve as the cognitive liaisons between internal and external representations. Support the externalist philosophy of mind.