Literature Review: Embodied Cognition

Andrew Kope

University of Western Ontario

The Role of Embodied Cognition in Time Perception

The human ability to understand and work with spatial concepts is crucial to our capacity to function in a three-dimensional environment. Recently, experiments have shown that spatial and motor resources are also used by humans in, for example, language comprehension that pertains to spatial concepts, the mental rotation of objects, and visual search tasks. These findings have prompted the theory embodied cognition, which suggests that humans use an evolutionarily older resource (bodily cognition – thinking about space and one's bodily position within it) to work with 'newer' ideas like language, theoretical space, and time. In the present paper several experiments and theoretical papers that are illustrative of the concept of embodied cognition are reviewed and explicated.

Barsalou (2003) is one of the primary researchers in the area of embodied cognition. He proposed the *situated simulation theory* as one explanation of the functioning of the human conceptual system. In his paper, he first explored three other theories of the conceptual system: semantic memory, exemplar models, and feed-forward nets. According to Barsalou, theories of the conceptual system can be broken down along five dimensions (modularity, method of representing knowledge, level of abstraction, stability of knowledge, and organization of knowledge). The semantic memory theory is described as modular (in that it treats memory of experiences as removed from memory for knowledge), amodal (in that units of knowledge are removed from their corresponding sensory representations), decontextualised (units of knowledge are detached from experience – like an encyclopaedic description), stable (remembering a given unit of knowledge is virtually identical over time), and taxonomically organized (more specific categories are nested within larger ones). The exemplar model theory is also described as modular, amodal, taxonomic and stable, however Barsalou indicates that it is situated (the storage of exemplar memories can include experiential detail). The feed-forward net model is similarly modular (one module underlies conception, and another underlies perception) and amodal (the connection between modules is arbitrary, and therefore amodal), taxonomically organized with information situated (storing more idiosyncratic knowledge about exemplars). Barsalou says, however, that feed-forward nets are highly dynamic, in that they represent categories with a space of representations, which can be differentially activated depending on its surrounding activation states. Finally, Barsalou's situated simulation theory is non-modular (instead of having separate systems for sensory-motor and conceptual processing, a representational system is responsible for both), modal (the same representations in the representational system underlie both perception and conception), situated (a concept is a "skill for constructing idiosyncratic representations tailored to the current needs of the situation" p. 521), dynamic (the simulator can construct many different simulations of the same concept, for different purposes, from different perspectives), and organized with an action-environment interface (concepts are organized around situated action, instead of taxonomies). In essence, Barsalou endorsed the situated simulation theory, which at the broad level states that the conceptual system develops to serve situated action, and on a specific level involves, for example, the use of simulators to create a conceptualization of an object that is contextually relevant to a goal-derived category for the purpose of achieving that goal.

Another main researcher in the area of embodied cognition is Rick Grush. Taking a different tack than Barsalou in his explanation of embodied cognition, Grush (2004) proposed the *theory of representation.* In his account, the brain constructs neural circuits that act as models of the body and environment, which are used in parallel with sensory information to provide expectations of sensory feedback - thereby enhancing and processing sensory information.

Importantly, these neural circuits can be ‘run offline’ to produce imagery, estimate outcomes of actions, as well as evaluate and develop different motor plans. An illustration of this theory presented by Grush is the effect of inner models on motor control. Grush explained that through the use of these neural circuits in combination with the body, the effects of feedback delay problems (the lag between estimated feedback signal from motor commands and the actual observed feedback signal) can be reduced. In concordance with Barsalou’s theory, Grush also believes that the framework of parallel neural circuits can be extended to use the offline functioning of an emulator of the motor-visual loop to create visual imagery. Finally, Grush explained that cognitive elements as evolutionarily novel as theory of mind phenomena, situated robotics, and language could all also fit within this embodied cognition framework based on his theory of representation.

Exploration of a more practical use of embodied cognition was done by Amorim, Isableu, and Jarraya (2006) who analyzed the presence of a cognitive advantage of imagined spatial transformations of the human body over imagined transformations of less familiar objects (e.g., Shepard-Metzler cubes). Over the course of six experiments, the researchers demonstrated that by supplying Shepard-Metzler cubes with bodily characteristics (i.e. by adding a head and arranging the cubes in a posture that humans can adopt) participants were able to complete mental rotations tasks significantly faster than if the Shepard-Metzler cubes lacked those body characteristics. They attributed this difference to the idea that imagined transformations of the body occur in less of a piecemeal fashion compared to imagined transformations of objects of a similar arrangement, and that difference is reflected in faster reaction times. It is important also to note that even with a head added to a Shepard-Metzler cube, if the ‘pose’ the cubes are in a position that cannot be adopted by a human being, there is no task facilitation by wholesale mental rotation.

Another important contributor to the theory of embodied cognition was Bernard Hommel (2009), who made two main contributions in his paper. Firstly, he adapted a model first proposed by James (1890) - whereby a motor cell fires (either arbitrarily or in response to input from a sensory cell), which causes a muscle to move, which is sensed by a kinaesthetic cell, which provides feedback to that same motor cell – to the theory of embodied cognition. Specifically, Hommel concluded the kinaesthetic cell would become a retrieval cue for the motor cell. In this way, recreating or anticipating the sensation in the kinaesthetic cell would be a means of activating the motor cell intentionally – that is, simulating an action provides a motor cell with the same necessary input to fire as sensory perception.

The second important point to be drawn from Hommel's (2009) paper is his *theory of event coding* (TEC). Hommel stated that this theory is a framework for explaining how stimuli and responses are represented and how "their representations interact to generate perception and action" (p. 512). He explained, for example, how this framework can be used to understand how preparation enables action control. He suggested that preparing for a task primes the task-relevant feature dimensions of the stimulus to be responded to (see below Wykowska, Schubo, & Hommel, 2009). Applied to embodied cognition, Hommel illustrated that priming action dimensions (i.e. the type of grasp or reaction action required to respond to a stimulus) affects task performance when the target is defined based on similar action dimensions (shape or size). This explanation of action control provided by Hommel's theory of event coding is slightly different, however still concordant with both Barsalou's (2003) and Grush's (2004) theories.

The theory of embodied cognition is not only being used to explain how we used shared mental motor resources to plan and simulate actions themselves, but also to explain more evolutionarily novel features of human cognition. Barsalou, Santos, Simmons, and Wilson (2008), for example, proposed the *language and situated simulation theory* (LASS) to explain how we represent knowledge. The researchers were sceptical of the existence of completely amodal knowledge representations in the brain, so instead proposed (based on situated simulation; Barsalou, 1999) that the brain captures modal states during perception, action, and introspection that it later simulates to represent knowledge. Similarly, the researchers suggested that these knowledge representations are *situated*. By situated, they meant that instead of simulating knowledge 'in a vacuum,' knowledge about something is simulated in the context of relevant introspections, settings, actions, and events. In their theory, language is incorporated through the use of activated linguistic forms that act as pointers to simulations that are potentially useful for representing the cuing word's meaning. For example, in speech comprehension a listener comprehends a speaker by assembling a simulation from their words and syntax that is (ideally) the same as the speaker's simulation which they are describing (the example used is of simulating a speaker's anticipated enjoyment at a concert).

To support their theory of language and situated simulation, Barsalou, Santos, Simmons, and Wilson (2008) cited findings from research in the area of abstract concepts. They argued that language alone cannot represent a concept. They used the example of describing the meaning of an abstract concept in a foreign language - the words alone do not hold meaning, but are only meaningful when one can ground the language in experience and simulate the concept. With regard to experimental technique, the authors suggest that although words are easy to use as laboratory stimuli, the use of words to the exclusion of pictures, sounds, touches, introspections and actions has led to distorted views of cognition in general and the conceptual system in particular. Correspondingly, they suggest that researchers study language and conceptualization in the context of experience.

Taylor and Zwaan (2008) did research work in a similar vein to that of Barsalou, Santos, Kyle, Simmons and Wilson (2008), suggesting that words activate brain areas for corresponding motor responses. They expected that the motor system would become active during comprehension of language that describes actions (motor resonance). They supported this hypothesis by citing previous research that had shown that sentences describing simple motor actions facilitate compatible motor responses (Glenberg & Kaschak, 2002) and activate the brain regions that are active when similar actions are performed (de Vega, Robertson, Glenberg, Kaschak, & Rinck, 2004). Extending their previous work (Zwaan & Taylor, 2006), in which they found that motor resonance both occurs immediately and is short lived (in the time-scale of language comprehension), their 2008 study investigated whether attentional shifts brought on by language could extinguish motor resonance (that is, adverbs that maintain the focus on action should facilitate motor resonance, whereas adverbs that shift the focus to the actor should extinguish it). In two experiments, they found that this was the case, and that attentional focus as modified by adverbs could affect motor resonance depending on whether they were actor-oriented, or action-oriented. In the conclusion of their paper, Taylor and Zwaan indicated that it is yet unclear whether motor resonance is top-down (e.g. understanding words in sentences affects motor activity) or bottom-up (e.g. motor tasks aid semantic word processing), however either would be consistent with their claim that semantic and motor systems rely on the same neurophysiological substrates.

Following the work of Taylor and Zwaan (2008) that indicated a shared brain region for linguistic comprehension and performance of actions, Wykowska, Schubo, and Hommel (2009) suggested that action planning (preparing grasping or pointing movements) biases visual search tasks. They posited first that the cognitive system weighs information relevant to the stimuli searched for higher than other stimuli – they are prioritized based on their dimension so as to have a higher chance of receiving the brain’s attention. The researchers then argued that preparing for a particular type of action prepares the actor to correspondingly process different types of information, which they tested in three experiments. Using both pointing and grasping experiments, Wykowska, Schubo, and Hommel found that preparing to take a particular type of action primes the processing of information related to that action. To account for these results, Wykowska, Schubo, and Hommel proposed a combination of Hommel et al.’s (2001) intentional weighting mechanism, and Wolfe’s guided search model (Wolfe, 1994). In this account, the authors proposed that the actor weighs perceptual dimensions according to intentions, and these weightings modulate perceptual signals in a bottom-up processing stream.

The papers reviewed presently have highlighted recent work that is illustrative of the concept of embodied cognition. Already explaining varied mental processes such as mental rotation of objects, knowledge representation, and language understanding, theories grounded in the idea of embodied cognition have momentum, and promise to provide further insight with coming research.

References

Amorim, M., Isableu, B., & Jarraya, M. (2006). Embodied spatial transformations: "Body analogy" for the mental rotation of objects. *Journal of Experimental Psychology*, *135*(3), 327-347.

Barsalou, L. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22,* 577-660.

Barsalou, L. (2003). Situated simulation in the human conceptual system. *Language and Cognitive Processes*, *18*(5/6), 513-562.

Barsalou, L., Santos, A., Simmons, W. K., Wilson, C. (2008). In De Vega, M., Glenberg, A., Graesser, A. (eds), *Symbols and embodiment: Debates on meaning and cognition*, 245-283.

de Vega, M., Robertson, D.A., Glenberg, A. M., Kaschak, M. P., & Rinck, M. (2004). On doing two things at once: Temporal constraints on actions in language comprehension. *Memory & Cognition, 32,* 1033-1043.

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

Grush, R. (2004). The Emulation theory of representation: motor control, imagery, and perception. *Behavioral and Brain Sciences*, *27*, 377-442.

Hommel, B. (2009). Action control according to TEC (theory of event coding). *Psychological Research*, *73*, 512-526.

Hommel, B., Musseler, J., Aschersleben, Gl., & Prinz, W. (2001). Codes and their vicissitudes. *Behavioral and Brain Sciences, 24,* 849-937.

James, W. (1890). *The principles of psychology* (Vol. 2). New York: Dover Publications.

Taylor, L., & Zwaan, R. (2008). Motor resonance and linguistic focus. *The Quarterly Journal of Experimental Psychology*, *1*, 1-9.

Wolfe, J. M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bulletin and Review, 1*, 202-238.

Wykowska, A., Schubo, A., & Hommel, B. (2009). How you move is what you see: Action planning biases selection in visual search. *Journal of Experimental Psychology: Human Perception and Performance, 35*(6), 1755-1769.

Zwaan, R., & Taylor, L. (2006). Seeing, acting, understanding: Motor resonance in language comprehension. *Journal of Experimental Psychology: General, 135*, 1-11.