Is Embodied Cognition Infallible or Falsifiable? Investigating the Thesis as a Sound Scientific Theory

Katherine A. Livins & Leonidas A.A. Doumas (klivins; leonidas@hawaii.edu)
University of Hawaii at Manoa, Department Psychology
2530 Dole St., Sakamaki C400, Honolulu, HI 96822

Abstract

Embodied cognition is a growing area of research within cognitive science—one that it is often presented as a framework that may help us account for cognition as a whole. It is, however, a theory and, as such, it must live up to the requirements that all scientific theories do. Of particular importance is the degree to which it is falsifiable. This paper investigates this issue.

Keywords: embodied cognition, embodiment, falsifiability

Embodied cognition has been a growing theoretical framework within the field of cognitive science for the past twenty years. It has influenced research on topics from low-level perception (e.g., Meteyard *et al.*, 2008) to high-level reasoning (e.g., Casasanto, 2009) and, as it continues to grow, it is often put forth as an organizing explanation of cognition in general (e.g., Schubert & Semin, 2009). That said, it is a *theory*—specifically, a scientific one. As a result it must be evaluated as any theory would be. To date, the field has done a reasonable job: confirmatory evidence has rolled in, and its methodologies have been refined (e.g., Spivey, 2007). However, despite the field's efforts to do good science through the lens of embodiment, one fundamental evaluation factor seems absent: "Is it *falsifiable*?" remains an open question. Given the importance of falsifiability to scientific enterprise, answering the question is necessary. Addressing this question of falsifiability is the goal of this paper.

Part 1: What is falsifiability?

Falsifiability is a cornerstone of scientific theory. As Popper (1963) argued, the difference between theories such as Freudian psychoanalysis and Newtonian physics lies not in whether it is possible to verify each theory, nor in whether they possess explanatory power (e.g., a way of explaining experimental results), but in their capacity to be debunked.

For a theory to be *falsifiable*, it is insufficient to only provide ways of supporting it. Instead, it must be possible to specify the types of evidence necessary for showing that the theory would *not* hold. Because it is impossible to directly observe a theory (since a theory is only an organizing principle built to explain a body of information or phenomena), defining only what would support it may allow for confirmation biases and the exclusion of important data. Thus, a scientific theory must involve making specific predictions about what must or should be observed if it holds, *and* what must or should not be observed if it does not.

Take, for example, the Bohr model of atomic structure. While it is unnecessary to go into detail, the model generally specified a structure of the atom and the way that its nucleus could be related to its electrons. Despite its seeming simplicity, the theory made predictions, including what the energy levels of certain atoms should have been if the theory was correct. Thus, boundaries of what the model could and could not account for were established. When these predictions were violated (e.g., multi-electron atoms displayed energy levels different from what the model predicted) the theory was falsified.

Having the ability to falsify a theory becomes crucial when competing theories exist. If each theory is not specific enough to make predictions, then it becomes impossible to decide which one (if any) is correct. Furthermore, theories that do not make such predictions are often over-generalized (e.g., Freudian psycho-analysis) such that they can account for almost any sort of data. As a result, they can be warped to account for any phenomenon, data, or unique case, creating a confirmation bias. In other words, they become explanatory catch-alls with little real explanatory power. Falsifiability protects against exactly these sorts of problems and, as a result, should play an important part in the development of any theory.

Part 2: Embodiment and Falsifiability

"Embodied cognition" is something of an umbrella term for work that is interested in the ways in which the body is involved in cognitive processing. In fact, there are so many definitions under the umbrella its boundaries are somewhat contentious. Take, for example, the quantitative issue of how many types of embodiment there are: Shaprio (2011) outlines three types; Wilson (2002) presents six, and there are more accounts still (e.g., Anderson, 2003; Ziemkie, 2003).

This lack of agreement could be considered a complication with regard to evaluating the falsifiability of embodiment; after all, if there exists multiple theories, then each one may require separate analyses. However, the heart of the differences usually centers on what it means *philosophically* for the body to be involved in cognition. For example, the *Enactive Approach* seems premised on the idea that there is no core self that resides inside a body, but that the self dynamically makes itself through interactions with the world. Furthermore, the world is not taken as pre-given, instead being shaped through the actions of the individual (Shapiro, 2011). As a result, all cognition is enacted through a symbiosis of body and world. *Situated cognition* is similar but it does not break down the concept of "self", instead maintaining a philosophic distinction between self and not-self (Shapiro, 2011). Cognition ends up being equally dependent upon (and shaped by) pressures from the world, though the self remains a meaningful unit of discussion and study.

Despite the many definitions that exist within the philosophic literature, cognitive scientists and experimental researchers, generally define and operationalize embodiment as some version of the claim that the body affects cognition, or that the body plays a meaningful role in it (whether that be through changes in perception and attention, differences in behavior, or the activation of neural motor systems) (e.g., Markman & Brendl, 2005; de Koning & Tabber, 2011). Thus, while there do exist competing philosophic offshoots of this basic idea, this more basic theoretical claim underlies most of them; it is at the heart of how the theory is defined and used empirically. The goal of this paper is to look at embodiment within this type of empirical (read, practical or scientific, not philosophic) context; we are interested in the ways in which experiments are designed when inspired by it, and the ways in which results are interpreted in light of it. In other words, we are interested in embodiment as a true scientific theory. If it does not live up to this type of scientific standard, it is important to ask whether it should be used as the basis for empirical work, or alternatively, whether there is something that can be done to make it live up to scientific standards. To the point, we proceed with an analysis of existing work, with an eye specifically towards whether the current application of embodiment meets the requirement of falsifiability.

To start this analysis we begin by looking at some of the research that has been done thus far. The remainder of this section will analyze two papers that investigate the affects of the body on cognition, and which are often cited as quintessential exemplars of this type of research. Special attention will be paid to the interpretations of the findings and their potential for allowing embodied cognition to be falsified.

Part 2.1

The paper "Action observation and acquired motor skills: An fMRI study with expert dancers", by Calvo-Merino *et al*. presents the idea that motor history affects future cognitive processing. It has been cited approximately six hundred times[1], often as evidence for a meaningful relationship between mind and body (e.g., Spivey, 2007; Barsalou, 2008).

The study addresses whether one's motor history affects one's ability to observe movements in others. For this project, a number of expert dancers (skilled in either ballet or capoeira), along with an untrained control group, were recruited. All participants were asked to watch videos of choreographed sequences from both dance styles. As participants watched the videos, neural activity was monitored with fMRI. Of interest were the premotor and parietal cortices, along with the superior parietal lobe and the superior temporal sulcus—areas previously associated with human action, and observation of action in others (Calvo-Merino *et al*., 2004; Grafton *et al.,* 1996).

The hypothesis was that activity in these areas would be strongest when watching a dance sequence that one had enacted firsthand. This result was observed. Calvo-Merino *et al.* argued that it must be the case that watching physical activity in others activates some sort of sensory-motor representation (Calvo-Merino, 2004), furthering the idea that bodily experiences affect cognition (as embodied cognition theory posits).

In order to address the degree to which this design offers the chance for falsification of embodied cognition, let us consider other possible outcomes of the study, and how Calvo-Merino *et al.* could have interpreted them. First, the dancers (and/or the control group) could have shown more neural activation when watching dance sequences that they had not engaged in firsthand. Embodiment could be supported by such a result equally well by arguing that the finding was due to a need for learning: motor areas activated more for understanding movements that could not, immediately, be made sense of by referencing past experiences. In fact, this interpretation would be consistent with other data, since it has been shown that the same motor areas that Calvo-Merino *et al.* were interested in demonstrate increased activation during visuomotor learning (Ghilardi et al, 2000). Consequently, whether or not the dancers showed more or less activation than controls, the embodied cognition thesis would still be supported given that bodily experiences would be shown to affect cognitive processing in either case.

Alternatively, the same activation could have been seen between the dancers and the control group, irrelevant of the observed sequences. However, this finding would not necessarily contradict embodiment either. Perhaps the *use* of representations does not require activation of the motor-systems, but encoding is entirely dependant upon them and, as a result, the body still affects cognition. Or, perhaps more radically, one might suggest that such an outcome implies that humans do not possess representations at all. In fact, this is a popular claim among some embodied cognition theorists (Varela, *et al*., 1992; Smith, 2005) and it could be that no difference was found between groups because there are no static representations stored in the

[1] Per GoogleScholar.

brain to be activated in the first place, leaving only motor areas to encode the video information.

While the possible interpretations of the results of the present study certainly indicate that embodiment theory is confirmable, it does not bode well for its ability to be falsified. In fact, it would be equally possible to explain Calvo-Merino *et al.'s* findings by adopting a competing perspective. A disembodied framework could be supported by suggesting that the dancers had encoded static representations of the sequences, which included the muscle groups necessary for performing them. This would account for why the motor areas of their brains lit up in response to watching them, without a need for participants to "simulate" anything. This explanatory flexibility is not a new idea; Mahon and Caramazza (2008) explicated the ways in which many findings that are supposed to support embodied cognition (such as Calvo-Merino *et al.*'s) may also be used to support a disembodied theory of cognition. It is troubling, though, that the theory's explanatory flexibility would exist no matter how the experiment turned out.

One could argue that the problems with this study are a function of how easily neuroimaging can be misapplied, and not of embodied theory itself. However, neuroimaging is a tool and, as such, there will always be ways to use it well and ways to use it poorly. It is quite possible to use this tool well (e.g., Engel *et al.*, 1994), but doing so requires the production of specific predictions so that the meaning of the scans can be clearly interpreted. A failure to do indicates a problem with the theoretical framework underlying the scans. In the case of the current study, the problem lays with the fact that any scan result could have been used to support embodied cognition. This is a problem of the theory, not of the technology.

Part 2.2

As another example, consider Tucker and Ellis' "On the relations between seen objects and components of potential actions" (1998). With almost as many citations[2] as Calvo-Merino *et al.*'s work, this study looks at whether the presentation of objects also potentates the affordances[3] that they allow from the human body. The primary concern of the study is how perception is affected by one's body, and the ways that one can interact with the world through it.

More specifically, the study looks at the relationship between the hand movements used when dealing with everyday objects and the ways that those objects are visually perceived. Tucker and Ellis argued that if an object's affordances are part of its representation, then it should be easier or faster to respond to the object with a physical movement that is somehow aligned with the affordance. They addressed this question by conducting three experiments.

First, they investigated whether participants would be faster to identify an object if it were presented in congruency with the hand responding to the presentation. For example, if a picture of a knife were presented in the direction that it would be grasped with the right hand, then the interest would be in whether a participant would press a response button more quickly with that right hand since movement in the right hand would be primed. However, an obvious problem is that this design does not determine whether participants are simply sensitive to left/right orientation, or handedness specifically. Thus, the second study asked participants to respond with two fingers on the same hand; the idea being that if participants were sensitive to handedness, instead of left/right orientation, then greater efficiency should not be demonstrated on a single hand.

Results indicated that participants responded more quickly to objects when they were presented in congruency with the hand that was pressing the button (i.e., with the hand that would be used to interact with the object as it was presented). Furthermore, this effect was not confused with simple left/right orientation or response since one-handed responses showed no difference in response times between left and right finger responses.

At first glance, these findings support the idea that an object's affordances are a part of how it is perceived and responded to. Consequently, they seem to support the claim that worldly interactions are embodied; however, if the other possible ways that the study could have turned out are analyzed in the same way that Calvo-Merino *et al.'s* study was, it becomes improbable that such a claim could have been denied.

First, Tucker and Ellis could have found that participants responded more slowly when a stimulus was presented to match the side of the grasping hand (i.e., the experiments' results had come out the opposite way). An obvious explanation for such a finding is that participants were asked to push a button instead of actually grasping – given that these are two distinct movements, it could have been that pushing buttons did not represent the affordances properly, causing interference. In fact, Tucker and Ellis realized this, and offered a third experiment to address it.

In the third condition, participants were given a new response method: responding involved the same wrist rotation and hand positioning that would be required for interacting with the presentation objects. Interestingly, Tucker and Ellis did not find a strong effect between hand positioning and response times, however, they concluded that their findings suggest that more than hand selection (left versus right) is involved in seeing

[2] Per GoogleScholar.

[3] A concept developed by Gibson (e.g., 1950), affordances are the potential ways in which one can interact with a given object (i.e., what sorts of bodily movements that object affords the human body).

and responding to objects (Tucker & Ellis, 1998).

Even if Tucker and Ellis had found a strong effect in their third condition, it would be difficult to argue with (i.e., falsify) any embodied interpretation. First, it could have been that participants responded to a stimulus with convergent affordances much more slowly than they responded to a stimulus with divergent affordances. While the exact meaning of such a finding is not obvious, it would suggest that there is some systematic relationship between the ways that we think about an object and the ways we can interact with it. Perhaps it could argued that when a stimulus is in congruence with the response action, we begin to activate the next step of movement necessary for interacting with the object and, as a result, move more slowly. For example, if we are presented with a teacup, perhaps we begin preparing our mouths for tea, or our throats for swallowing. Such an interpretation would be supported by other experimental data, which suggests that visually controlled grasping motions (especially in children) are preceded by a series of planning motions, sometimes causing longer response times if the plan is non-ideal (Hofsten & Ronnqvist, 1988). Alternatively, embodied cognition often posits that representations (if they exist) are dynamically updated to include experiences (Smith, 2005). It could be argued that more processing time is required to recode a perceived thing based on new data.

Finally, it could have been the case that Tucker and Ellis found no relationship at all. Such a null result would likely be interpreted as puzzling and could be explained away by pointing out that this experiment (like any) required a commitment to a specific methodology and, therefore, specific types of movement and stimuli. One could argue that the movements chosen by Tucker and Ellis were simply non-ideal for demonstrating a relationship (perhaps a knife is more about chopping or sharpening than grasping, and perhaps tea cups are more about sipping, pouring, washing, dunking or even swallowing).

In short, the experiment, although motivated by a prediction of the embodied theory of cognition, provided no easy means for falsifying that theory without running conditions with every possible movement ever associated with a given object. However, even then, research into perceptual dominance could be mobilized to explain such null results, For example, it appears that some sensory modalities are more dominant than others. Vision is often considered the most dominant of human modalities (Sinnett *et al.,* 2007). As a result, any study that is interested in the embodied relationship between vision and bodily movement, and that involves visual stimuli while looking for manual or tactile responses, may be considered flawed in that it could be the case that simply showing a participant a visual stimulus activates more visual experiences or representations (embodied or otherwise) than hand-oriented experiences or representations. If it is the case that visual responses dominate motor responses, then any null results from a methodology employing visual to manual responses could be criticized and dismissed.

Importantly, we are not suggesting that anyone would actually use some of these alternative outcomes to demonstrate that embodied cognition *is* the case (e.g., that some absence of proof is proof for the thesis). The point is that all of these outcomes *can* be dealt with within an embodied framework. Consequently, it does not appear that this experiment (like the last) offers much by way of an opportunity for falsification.

Part 2.3

We are not lodging any sort of specific attack on the researchers whose work we have reviewed (these papers were selected for their popularity and clarity). Our concern is that given such experiments are used as support for embodied cognition *qua* a scientific theory (e.g., for Calvo-Merino's paper, Gallese, 2008; Barsalou, 2008; de Konin, 2011; and for Tucker and Ellis' paper, Wilson 2002; Semin & Smith, 2008). It is problematic that such experiments could accommodate, or even explicitly support, an embodied account, no matter how they turned out.

Likewise, we are not trying to discredit any of the subtheories or philosophic work that has been inspired by embodied cognition; certainly, their subtheories, and empirical work based on those theories, that do make and test predictions (e.g., Gray *et al*, 2006; Hommel *et al*, 2001). However, embodied cognition itself is not just an inspirational tool—it is posited as a theory in and of itself, and at this point, it is one that seems remarkably susceptible to methodologies that suffer from confirmation biases.

Part 3: Can We Fix The Problem?

Just because something has not been done, does not mean it cannot be. Thus, it seems important to look at embodied cognition and to determine whether it is theoretically *possible* to falsify. We begin by making the requirements of falsification explicit.

For a theory to be useful scientifically, it cannot simply lend itself to supporting research, but must also be sensitive to the ways that it could be shown *not* to hold. This requires specificity: "theory *x* would be untrue if *y* (and *z* and […]) were to happen", where *y* and *z* are observable, measurable and definitive. Doing so ensures that everyone (both supporters and dissenters) can recognize when it is time to abandon the theory. Furthermore, we must accept the possibility (no matter how small) that the theory will be falsified. Falsification would not be such a bad thing though—after all, it would mean that we get an opportunity to build a new, more complete theory of cognition.

Currently, embodied cognition does not seem to have these sorts of specific boundaries. To date, the closest attempt seems to be a set of claims explicated by Wilson (2002). Unfortunately, even they seem too vague (i.e., unobservable, unquantifiable, indefinite) to act as falsifying predictions. To see this vagueness in action, we consider the first three.

First, Wilson argues "cognition is situated". That is, cognition takes place in an environment and, therefore, cannot take place without perception and action. It is studied by looking for the ongoing impact of perceptual input during cognitive tasks (Wilson, 2002). However, if this claim is a concrete prediction (open to falsification), then embodied cognition fails whenever such tasks are completed without perception or action. However, Wilson herself posits that this prediction may not hold for all types of cognition; she points out that some things do not always rely on the intake of new information (her examples include planning, reasoning, etc.). Thus, the claim does not involve a clear list of conditions under which it does or does not hold. As a result, it seems more like a "sometimes" prediction than a definitive one.

Second, embodied cognition is supposed to support the idea that cognition is "time pressured" (i.e., that, when pressured to work quickly, cognition can differ). This claim does not make any more forward momentum than the first. If it is a prediction, then falsification should occur any time that cognition does not change based on time-pressure. While, of course, many cognitive activities do, Wilson herself provides us with examples of "time-locked" cognition, such as skilled hand movements (Wilson, 2002). As a result, if this claim is a crucial prediction, the thesis is already in trouble. Alternatively, if it is a "sometimes" prediction like the last claim, then it is simply not specific enough.

Third, embodied cognition expects that we "off-load" cognitive work onto the environment. This claim is evidenced by the fact that people make use of items from the world to solve problems (thus lessening the work required of processes such as working memory). Obviously though, there are times that tasks are not off-loaded, even within the realm of a single task. For example, when determining where furniture should go in a room, it is possible to move it around or draw a diagram, or to visualize different patterns that may be used. It is also possible to mentally map the room instead. Embodied cognition is not definitive enough to predict the "why", or enough of the "how", to account for anything more specific than that it *can* happen. This seems incomplete and, again, not usefully predictive.

Because of space constraints, we cannot engage in a similar analysis of the other three claims. As they are, though, they offer no opportunity for falsifiability as they also reduce to variations of "the body is important for cognition under some conditions". While it is true that such a claim can be turned into experimental work, it is not enough to fill out the statement, "theory *x* would be untrue if *y* (and *z* and […]) were to happen" with observable, measurable and/or definitive claims. Without the capacity to produce such claims, embodied theory remains unable to produce sufficiently specific predictions to be falsified.

Basing empirical work on a theory with an unclear foundation can be problematic. Any experiment (like those in Section Two) will have confusing results. No matter how such a study turns out, it can account for the data within the embodied framework, and any null result can be dismissed. This lack of definitiveness leaves researchers that are already invested in embodiment frozen in unsolvable debates without a real possibility of coming to a conclusion, let-a-lone unifying cognition. Similarly, researchers outside the debate may have trouble finding application for embodiment within their own domains.

Newell (1973) argued that Cognitive Science is often guilty of discovering a phenomenon, doing a plethora of experiments to explore it, and never moving on to think about what the research "means". It seems that this "plethora" point is where embodied cognition is now—at the crux of exploration and synthesis, with a real opportunity to move forward. The collection of confirmatory data definitely suggests that the body is likely important for cognition *in some way*, however, we have yet to answer what this way is in a specific or systematic sense, and this is what needs to be changed.

We are not suggesting that there is a quick fix, however, we believe this issue of falsifiability can guide future research in a meaningful way: Researchers need to start asking a few questions every time they invoke embodiment. First, asking, "Under what specific conditions do we expect this cognitive process to be embodied?" in combination with, "What cognitive functions are most penetrable to bodily or action-based manipulations (and which are not penetrable at all)?" will allow for the boundaries of the theory to be reigned in. It is unlikely that the answer to every cognitive mystery is "embodiment", so we need to commit to specific claims about when we think embodiment is meaningful and to what processes we think it makes an important difference. Second, asking "What would it mean for embodiment, as a theory, if my results came out differently?" will force attention to the issues raised in this paper. If this answer cannot possibly be "it would suggest that process *x* is not embodied", then the methodology may need to be revised.

We are certainly not saying that embodiment should be dismissed (quite the opposite, actually). However, to the extent that embodied cognition is going to be used as a theory, limiting cases need to be defined. Any research that does this is a step in the right direction, and would be useful, not only for the embodiment community, but also for interested outside observers.

We cannot offer a definitive end point for such efforts—we wish we could provide a fast, or easy answer, however developing a comprehensive theory that is aimed at organizing cognition in a deep and meaningful way is not a simple task. Our goal is simply to point out what we see as an important problem. It is our hope that those dedicated to embodied cognition research will respond by becoming more sensitive to the issues raised here, and that, as a result, these researchers will start making their claims more explicit and, more importantly, begin establishing limiting cases of the theory.

Works Cited

Anderson, M.L. (2003). Embodied cognition: a field guide. *Artificial Intelligence*, 149, 91-130.

Barsalou, L.W. (2008). Grounded Cognition. *Annual Review of Psychology*, 59, 617-45.

Calvo-Merino, B., Glaser, D.E., Grezes, J., Passingham, R.E., & Haggard, P. (2004). Action Observation and acquired motor skills: An fMRI study with expert dancers. *Cerebral Cortex, 15.8, 1243-1250.*

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General*, 183.3, 351-367

Descartes, R. (1641). Meditations on first philosophy. In R. Ariew (Ed.), *René Descartes: philosophical essays and correspondence* (pp. 97-141). Indianapolis: Hackett Publishing Company Inc.

Engel, S.A., Rumelhart, D.E., Wandell, B.A., Lee, A.T., Glover, G.H., Chichilnisky, E.J., & Shadlen, M.N. (1994). fMRI of human visual cortex, *Nature, 369*, 525.

Gallese, V. (2008). Empathy, embodied simulation and the brain: Commentary on Aragno and Zepf/Hartmann. *Journal of the American Psychoanalytic Association*, 56, 769-781.

Gibson, J.J. (1950). The perception of the visual world.Oxford: Houghton Miffin

Ghilardi, M.F., Ghez, C., Dhawan, V., Moeller, J., Mentis, M., Nakamura, T., Antonini, A, Eidelberg, D. (2000). Patters of regional brain actiation associated with different forms of motor learning. *Brain Research*, 871, 127-145.

Grafton S.T., Arbib, M.A., Fadiga, L., & Rizzolatti. G. (1996). Localization of grasp representations in humans by positron emission tomography: Observation compared with imagination. *Experimental Brain Res,* 112. 103-111.

Gray, W.D., Sims, C., Fu, W.T., & Schoelles, M.J. (2006). The soft constraints hypothesis: A rational analysisof resource allocation for interactive behavior. *Psychological Review*, 113.3, 461-482.

von Hofsten, C., & Ronnqvist, L. (1988). Preparation for grasping an object: A developmental study. *Journal of Experimental Psychology*, 14.4, 610-621.

Hommel, B., Musseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework of perception and action planning. *Behavioral and Brain Sciences*, 24, 849-937.

de Koning, B.B., & Tabbers, H.K. (2001). Facilitating understanding of movement in dynamic visualizations: an Embodied Perspective. *Educational Psychological Review,* 23, 501-521/

Mahon, B.Z., Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology – Paris*, 102, 59-70.

Markman, A.B., Brendl, C.,M. (2005). Constraining theories of embodied cognition. *Psychological Science*, 16.1, 6-10.

Meteyard, L., Zokaei, N., Bahrami, B., & Vigliocco, G. (2008). Visual motion interferes with lexical decision on motion words. *Current Biology,* 18.17.

Newell, A. (1973). You can't play 20 questions with nature and win: Projective comments on the papers of this symposium. In W.G. Chase (Ed.), *Visual information processing* (pp. 283-308). New York: Academic Press.

Popper, K. (1963). Science as Falsification. In *Conjectures and Refutations*. New York: Routledge

Semin, G.R., & Smith, L. (2008). *Embodied grounding: Social, cognitive, affective and neuroscientific approaches.* Cambridge: Cambridge University Press.

Schubert, T.W., & Semin, G.R. (2009). Embodiment as a unifying perspective for psychology. *European Journal of Social Psychology,* 39.7, 1135-1141

Shaprio, L. (2011). *Embodied cognition*. New York: Routledge

Sinnett, S., Spence, C., & Soto-Faraco, S. (2007). Visual dominance and attention: The Colavita Effect Revisited. *Perception and Psychophysics,* 69.5, 673-686.

Smith, L.B. (2005). Cognition as a dynamic system: Principles from embodiment. *Developmental Review*, 25, 278-298.

Spivey, M. (2007). *The continuity of mind*. New York: Oxford University Press.

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.

Varela, F., Thompson, E., & Rosch, E. (1992). *The embodied mind: Cognitive science and human experience.* Cambridge: MIT Press.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review,* 9.4, 625-636.

Ziemke (2003). What's that thing called embodiment? In: Alterman & Kirsh (Eds.) *Proceedings of the 25th Annual Conference of the Cognitive Science Society* (pp. 1134-1139). Mahwah, NJ: Lawrence Erlbaum