DE GRUYTER OPEN

STUDIES IN LOGIC, GRAMMAR AND RHETORIC 41 (54) 2015

DOI: 10.1515/slgr-2015-0017

Guilherme Sanches de Oliveira
University of Cincinnati, USA

Anthony Chemero
University of Cincinnati, USA

AGAINST SMALLISM AND LOCALISM

Abstract. The question whether cognition ever extends beyond the head is widely considered to be an empirical issue. And yet, all the evidence amassed in recent years has not sufficed to settle the debate. In this paper we suggest that this is because the debate is not really an empirical one, but rather a matter of definition. Traditional cognitive science can be identified as wedded to the ideals of "smallism" and "localism". We criticize these ideals and articulate a case in favor of extended cognition by highlighting the historical pedigree and conceptual adequacy of related empirical and theoretical work.

Keywords: extended cognition, reductionism, internalism, affordances, dynamical systems, tool-use, social interaction, cognitive institutions

1. Extended Cognition: the Debate and the Evidence

Cognitive science is traditionally associated, in its origins, with the demise of behaviorism, and interpreted as the rejection of the then dominant externalist approach, which limited the scope of psychological investigation to the relationship between environmental stimuli and behavioral responses, and its replacement by an internalist view that re-legitimized, through the computer metaphor, talk of mental states, consciousness, and eventually a host of unobservable, theoretical concepts. Although cognitive science thus construed (or caricatured) may still be the dominant paradigm, powerful alternatives have gained increased attention in the past few decades. Already at the end of the twentieth century a trend was evident: "cognitive science is being pulled vertically down into the brain and horizontally out into the environment" (Bechtel, Abrahamsen, & Graham 1999, p. 90). The debate about the nature of cognition, particularly whether cognition can ever *extend* beyond the head and the body is representative of this trend, especially of the expansion into the environment—although very interesting and relevant work has also been done on the

ISBN 978-83-7431-450-3 ISSN 0860-150X

cognitive neuroscience front to support the related but distinct idea that cognition is *embodied*. In this section we sketch a summary of the evidence and the debate over extended cognition. Despite all the empirical support available, the debate is far from settled—an issue that we address in section 2.

The evidence for extended cognition is varied, and can be separated in at least two very distinct groups, comprising, on the one hand, informal evidence from phenomenology and thought experiments, and, on the other hand, a host of actual experimental results. Beginning with the more intuitive and mundane cases, the phenomenological evidence is that we routinely experience things that are not parts of our bodies as being parts of our bodies. Visually impaired individuals, as Merleau-Ponty famously claimed, do not usually perceive the walking cane itself, but rather perceive "the world at the end of the stick" (1962, p. 142). But examples abound also for those of us with intact eyesight. When riding a bicycle, for instance, we feel not the bicycle itself but rather the bumps on the road as though we were hitting them directly. The same applies for seasoned drivers, whose experience is never detached as that of sitting in a fast-moving metal box and interacting with it, but rather as though interacting with the world and feeling the road (and other cars, in the case of an accident) through the car. And similarly in playing baseball or softball for the 1000th time, one need not attend to the bat but only hit the ball as if the bat was an extension of one's arm. Ordinary examples such as these have also inspired a number of thought experiments, with the most famous one being that of Otto and his notebook. Looking at a simple event such as meeting a friend at the museum, Andy Clark and David Chalmers considered *how* a normally-functioning person remembers not only the appointment itself but also the museum address and how to get there, and compared that to a hypothetical individual (Otto) who suffers from Alzheimer's disease and habitually uses a notebook to record important information such as appointments, addresses, and directions. Clark and Chalmers' conclusion was that the notebook should be seen as an extension of that individual's cognitive abilities: "If, as we confront some task, a part of the world functions as a process which, *were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the cognitive process" (Clark & Chalmers, 1998, p. 8, italics original).

But the evidence in favor of extended cognition goes far beyond the phenomenology of ordinary experience and the intuitive appeal of thought experiments. The evidence from actual experiments is actually so vast that

we could not hope to do justice to it in this short paper. Instead, then, we will simply mention some of the research on perception, the brain, and motor systems, and let the reader follow the references as desired. Much of the work we will focus on can be identified as part of the research program of "Radical Embodied Cognitive Science" or simply RECS (Chemero, 2009, 2013), which utilizes the explanatory tool of dynamical systems theory (Kugler, Kelso, & Turvey, 1980) to study the basic unit of perception–cognition–action. But the real unifying point of this work is the theoretical perspective of ecological psychology (Gibson, 1979). This means that the bulk of this research focuses on *affordances*, which are understood as relations between the physical properties of the world and the action capabilities of the body. The basic insight, then, is that the body is in constant flux, at multiple time scales, as are an animal's abilities to act. And because the affordances for an animal depend on that animals' action abilities, the affordances for an animal are also in constant flux. Over developmental timescales in humans, there are changes in strength, flexibility, and coordination (see Adolph, 1997, 2008); and over behavioral timescales, changes in posture and locomotion alter action capabilities, as do also *attachments* to the body. Based on this observation, an important line of empirical research has focused on how action capabilities determine what physical properties an object must have to afford a certain behavior, resulting in the identification of "affordance thresholds" (e.g., Ishak, Adolph, & Lin, 2008) that are characteristic in perceiving affordances. Related strands of research with relevant empirical results include the following:

- Research focused on tool-use and the emergence of *person plus object systems* suggests that the dynamics of a person+object system are often entirely different from those of the person without the attached object (Wagman & Taylor, 2004, 2005a, 2005b). Moreover, perceiving what behaviors are possible for the person+object system means perceiving the world in relation to this dynamical system (Bongers, Michaels, & Smitsman, 2004). This has led to the conclusion that successful control of the person+object system is tantamount to controlling a novel dynamic system (Jagacinski & Flach, 2003; Wickens, 1986).

- Some of the empirical work has looked at how a large carried object changes the *shape* of the body and hinders the ability to pass through apertures. Warren and Whang (1987) identified the following relationship: affordance threshold = aperture width / shoulder width $\cong$ 1; building on that work, Wagman and Taylor (2005) deter-

mined the relationship as: affordance threshold = aperture width / object width ≅ 1. What these results show is that attached objects that change a perceiver-actor's geometric properties are treated behaviorally as extensions of the body.

- Work on the dynamics of persons+objects shows that attachments to the body also change *action capabilities* by changing the dynamic properties of the perceiver-actor. Bhalla and Proffitt (1999; Proffitt, 2006) find that subjects perceive hills as steeper when they are wearing heavy backpacks. It is important to note that wearing backpacks does not just make it more difficult to climb hills, it also changes subjects' center of mass. Wagman and colleagues (Malek & Wagman, 2008; Regia-Corte & Wagman, 2010) had subjects wear backpacks on front and back, and asked them to judge whether they could stand on an inclined plane (subjects were asked, therefore, to make a judgment about an affordance). And not surprisingly, subjects judge that they can stand on steeper inclines when they have the pack on their fronts. That means that attached objects that change a perceiver-actor's dynamic properties are treated behaviorally as extensions of the body.
- Merleau-Ponty's point about the blind man's cane applies more broadly to understanding how amputees perceive through prosthetic limbs, surgeons perceive through laparoscopic tools, and cyclists and drivers perceive the road through vehicles. These abilities are continuous with the ways animals perceive through nonenervated appendages (hair, nails, claws, quills, horns, whiskers, antennae, etc.). Empirical research shows that affordances can be perceived by means of extended haptic perception (Burton, 1992; Fitzpatrick et al., 1994; Wagman & Taylor, 2005a). For example, merely by exploring a surface with a hand-held object, a novice subject can determine whether a gap in that surface can be stepped across (Burton, 1992). This motivates the conclusion that humans perceive affordances through tools that extend the body.
- If a hand-held tool is experienced as an extension of the body, then use of a hand-held tool that changes the action capabilities of a perceiver-actor may influence subsequent motor behaviors performed without the tool. Cardinali, Frassinetti, Brozzoli, Urquizar, Roy, and Farne (2008) had subjects use a reaching tool that extends reaching distance by 40 cm. After using the tool, participants perceived consecutive touches on their arms and hands as being farther apart than they were perceived as being before using the tool. After using the tool, subjects reached as if their arms were longer than they in fact are. Cardinali et al. interpret

this as having happened because the tool was incorporated into the participants' understanding of the scale of their bodies, neurally implemented as a "body schema". As a result, using a tool that extends the body changes behavior, and causes lasting changes to the way that the brain controls the body.

- Another group of empirical work worth mentioning focuses on what is called *1/f noise* (or "pink noise"). Detecting 1/f noise in a system indicates that the system is a unified, self-organizing system: ". . . 1/f noise would have to be a cooperative phenomenon where the elements of large systems act together in some coordinated way" (Bak, 1996). Moreover, 1/f noise indicates that a system is interaction dominant (van Orden, Holden, & Turvey, 2003). Research shows that 1/f noise or pink noise is ubiquitous in well-functioning, physiological systems, such as neural firing patterns, heart beat blood volume, gait; when coordination is disrupted, these systems also exhibit uncorrelated variability or white noise. More importantly for our purposes, there is evidence that 1/f noise can be found in instances of tool-use and person+object systems: that is what was observed by Dotov et al. (2010) and expanded by Dotov and Chemero (2014). More recently, still, this was shown using the Enactive Torch, a sensory substitution device (Favela & Chemero, in press).

Having briefly reviewed some of the evidence in favor of extended cognition, we can now turn to the debate itself. As the dialectic is usually described, the debate about extended cognition began with the claim that evidence (such as that mentioned above) shows that cognitive systems are not in principle bound by skull and skin (a position put forward by, e.g., Clark, 1997; Clark & Chalmers, 1998). Critics of extended cognition reacted to this suggestion by saying that the inferences from thought experiments and actual experiments are fallacious for two reasons: to begin with, things outside the skin and skull are not of the right sort to be parts of cognitive systems (Adams & Aizawa, 2001); moreover, these (thought) experiments merely show that cognitive systems are situated, embedded, and/or embodied (Rupert, 2004). Advocates of extended cognition, in turn, countered that the arguments against extended cognition are mere armchair philosophizing: they beg the question by making it in principle impossible for cognition to be extended, and thus should not be taken as telling against a contingent empirical claim (Wilson & Clark, 2009). But critics responded by claiming that their arguments against extended cognition are not armchair philosophizing: whether cognition is extended is a contingent, empir-

ical claim, and as a matter of contingent empirical fact, cognition is not extended (Adams & Aizawa 2001, 2008; Rupert, 2009).

2. The Real (Conceptual) Disagreement

We have just seen that key players on both sides of the debate agree that whether there is such a thing as extended cognition is an empirical question. This should be seen as good news, pointing to a possible solution to the debate: empirical evidence in favor of extended cognition, if there is any, should bring to an end disagreement on the matter. However, all the evidence (such as that mentioned in section 1, and much more) has not been sufficient to convince the critics. We believe that this is because the question whether cognition can be extended is not really an empirical one, but rather it is a matter of definition. This means that ontological presuppositions and methodological assumptions about *cognition* precede and determine what evidence can be obtained about whether it can be *extended* or not.

Consider this statement by critics of extended cognition of how they see the evidence:

> as a matter of contingent empirical fact, human tool use is typically a matter of intracranially localized cognitive processes interacting with extracranial biological, chemical, and physical processes. Current human use of pencils and paper, computers, watches, telescopes, and hearing aids are all properly understood as cases in which cognitive processes interact with noncognitive processes. (Adams & Aizawa 2009, p. 78)

This quote expresses in very clear terms the idea, defended by critics and advocates alike, that extended cognition is a matter of contingent empirical fact. But more importantly for our present purposes, the quote also betrays the real conceptual (rather than empirical) basis of the disagreement. The focus on "intracranially localized cognitive processes" is representative of the views paradigmatically inimical to extended cognition, and, to an extent, typical of mainstream cognitive science, which can be identified as "smallism" and "localism". Smallism is the contention that mature cognitive science will explain in terms of the smallest aspects of physical reality (Wilson, 2004). The ontological underpinning of smallism is that "mental states and functions are determined by the smallest scale of physical reality inside or intrinsic to a cognitive system" (Chemero & Silberstein 2008, p. 129). Smallism is characteristic of purely reductionist approaches but is also a driving force behind contemporary cognitive neuroscience. Localism,

in contrast, is the contention that mature cognitive science will explain in terms of proximal causes of action inside the brain of the agent. This claim is based on the ontological view that "mental states and functions reside inside the head" (Chemero & Silberstein, 2008, p. 129). Smallism and localism are, therefore, entirely independent views, such that one could be committed to one of them and not the other; and still, they quite clearly go hand in hand.

In one reading, smallism and localism could be interpreted as "predictions" for the future of cognitive science, amounting to empirical claims that could be proven correct or incorrect depending on what future cognitive science turns out to be like. That is in fact an idea that has been openly expressed:

> In the end, empirical research should decide this question: we should commit resources to the framework of extended cognitive systems, apply the extended view in the study and the lab, and see whether doing so generates a flourishing research program in cognitive science. It is very difficult to predict the future of science; matters might work out in favor of extended systems. There are, however, reasons for pessimism. (Rupert, 2004, pp. 425–426)

More generally, however, smallism and localism are statements of value about what kind of scientific work one deems worth pursuing, normative claims about the kind of science one is committed to building, and consequently methodological directives for that ideal of science. The two interpretations are not unrelated: as the quote above suggests, what one thinks the future will be like (the predictive aspect) informs what one considers worth pursuing in the present (the normative-methodological aspect), and vice versa.

It is our contention that even where smallism and localism are not openly endorsed, it is not the evidence but rather conceptual divergence that is responsible for the continuation of the extended cognition debate. This is because, given the explicit or merely implicit commitment to smallism and localism (which are not empirical claims), no quantity or quality of evidence could possibly settle the debate. Rather than riding on empirical results and interpretations of those results, the extended cognition debate is therefore a debate about how to define the word "cognition". For internalists in the debate (Rupert, Adams, Aizawa), cognition is defined in terms of computational manipulations of representations. But computational manipulation of representations is not part of the explanatory toolkit of those who gather evidence on extended cognition. These cognitive scientists work outside the paradigms of smallism and localism. This assessment of the

conflict raises a series of questions, a couple of which are particularly worth mentioning.

First, the reader might wonder, if the debate is not empirical, then how will it be solved? If not empirical evidence, then what will settle the debate? A perhaps disappointing answer is that it likely will not be settled! At least in the short run, we can expect to see both paradigms receiving attention from researchers as well as institutional support and funding, and also to produce results in consonance with what has been observed up to now. Ultimately, however, we believe anti-smallism and anti-localism will prove to be a coherent, robust, and highly productive research paradigm (see e.g. Chemero & Silberstein, 2008).

The second question might seem more pressing to those who endorse smallism/localism and thereby reject the idea of extended cognition. When the debate is framed, as it usually is, as essentially an empirical one, then critics react as if those working in extended cognitive science are dealing with defective evidence and/or incorrectly interpreting the evidence. But if the extended cognition debate is, as we claim, not empirical but one of definition, then critics might wonder: are advocates of extended cognition simply changing the subject? If the debate really is a disagreement about how to understand the word "cognition", then the critic might think that, by adopting a different definition to begin with, those who go against mainstream smallist/localist cognitive science are not offering a competing account but are simply doing something else. This is a mistaken view: not only is extended cognitive science not changing the subject, but mainstream smallist/localist cognitive science itself might instead more justly be charged with changing the subject. We will elaborate on this point in the final section.

3. Against Smallism and Localism: Back to the Future

The received view of the history of the extended cognition debate focuses on developments in the 1990s, as was made clear in the dialectic sketched at the end of section 1. A key event in the "pre-history" of the debate is Edwin Hutchins' (1995) study of distributed problem solving as by ship crew members in interaction with instruments and tools. Just a couple of years later the "official" start of the debate occurred when Clark and Chalmers (Clark, 1997; Clark & Chalmers, 1998) made a big splash among scholars working in cognitive science, philosophy of mind, and cognate areas. Much of the subsequent discussion by philosophers and psychologists has accord-

ingly focused on whether "external"—i.e. extracranial—components (such as the ship's instruments and crew members or Otto's notebook) are mere aids to cognitive processing or whether they are truly constitutive of that activity. However, this received history of the debate belies the history of extended cognition. In taking extended cognition to be a brand new idea, critics demand concrete evidence to motivate the adoption of the alleged "novel competing paradigm"; as we have seen, however, no amount of evidence has sufficed to settle the debate because the disagreement is first and foremost a conceptual one. What we want to indicate in this last section is the additional point that extended cognition is not that novel or revolutionary a paradigm, and many of the foundational insights can be found already with William James, a century before the "official" start of the received history of the debate. Looking back at the real historical antecedents of extended cognition gives us a fresh perspective on the present and future of extended cognition and the debate about it. For this reason, after a quick look at the history of extended cognition, we will close the paper by briefly mentioning a couple more ongoing research projects that accordingly embody the stance of anti-smallism and anti-localism.

A central historical antecedent of embodied cognition research is Gibsonian or ecological psychology (Gibson, 1979), which is founded on three precepts: first, that perception is direct (rather than involving producing and processing internal representations); second, that perception is not passive, but always action-oriented—that is, perception is in principle and in practice inseparable from our exploring the world; and third, that perception is of "affordances" or "opportunities for action". In other words, this means that we do not perceive the physical properties of objects in the environment and then need to internally process those inputs in order to act, but rather that we simply and directly perceive what we can do in the environment. An interesting consequence of ecological psychology is that it blurs the distinction between the subjective and the objective: affordances are subjective, or "relative to the animal" and "unique for that animal" (Gibson, 1979, p. 127), but they are also "objective, real, and physical" (Gibson, 1979, p. 129) in the sense that an "opportunity for action" exists for an animal even if that animal is not aware of it. Another important consequence of ecological psychology is that it provides a framework for understanding intelligent behavior with no need for internal representation processing, what Chemero (2009) calls "mental gymnastics".

Interestingly enough, this recent antecedent of extended cognition actually takes us even farther back in history. That is because the ideas just mentioned owe much to the pragmatist tradition, especially William James

and John Dewey, whose work problematized the distinctions between fact and value, subject and object, and thought and action. In his pioneering work, James rejected his contemporaries' atomistic approach to psychological experience, proposing instead that "the science be as vague as its subject" (1890, p. 6). And still, he provided a clear definition or criterion for "the mark of the cognitive" by identifying goal-orientation as characteristic of intelligent agency: "The Pursuance of future ends and the choice of means for their attainment, are thus the mark and criterion of the presence of mentality in a phenomenon" (James, 1890, p. 8). In contemporary terms, this could be reframed as stating cognition to be the ongoing, active, purposeful maintenance of a robust animal–environment system, achieved by closely coordinated perception and action. Still, long ago James already used this criterion to delineate the object of study of psychology and exclude reductionist descriptions:

> I shall then adopt this as the criterion by which to circumscribe the subject-matter of this work so far as action enters into it. Many nervous performances will therefore be unmentioned, as being purely physiological. Nor will the anatomy of the nervous system and organs of sense be described anew. (James, 1890, p. 11)

More than the developments in the 1990s that start what we have called the "official" history of the debate, it is this basic insight dating back to James that motivates rejecting smallism and localism and provides the foundation for research on embodied cognition. And this longer history also continues in related work that is representative of anti-smallism and anti-localism. Going beyond the focus on tools and artifacts, and the role they can play in person+object systems, some have argued that cognition is also extended *socially* through interpersonal interaction. John Sutton, for example, has worked on the contribution of interpersonal interaction to remembering, in what he describes as "empirical research on socially distributed remembering, aimed at identifying conditions for mnemonic emergence in collaborative groups" (Sutton et al., 2010, p. 521). Sutton and colleagues observed that, for closely related people, remembering is often a collective task that is performed through interaction: "couples and families, or other enduring and integrated small groups such as old school friends, veterans, sports teams, committee members, or business partners often and repeatedly jointly remember significant episodes they have gone through together" (Sutton et al., 2010, p. 539). While some accounts like Clark and Chalmers' have relied on the functional similarity of "internal" and "external" components, Sutton and colleagues adopt a different strategy: "The

focus is not on whether or how much the internal and external resources have features in common, but on how they operate together in driving more-or-less intelligent thought and action" (Sutton et al., 2010, p. 525). As such, by using what they call "transactive memory systems", the researchers suggest that we find in socially distributed remembering a case of "socially coupled dynamical system with emergent properties, which in certain cases can be highly integrated and enduring, and exhibit high levels of continuous reciprocal causation" (Sutton et al., 2010, p. 547). This quite obviously goes against smallist or localist accounts of memory, but, importantly, it is not merely a promising approach but rather an already productive line of research.

Further developments in this conceptual framework suggest that, beyond tool-use and interactive contexts, coupling with "cognitive institutions" can be a form of socially extended cognition as well. Shaun Gallagher and colleagues have termed "cognitive institutions" the culturally-established, socially-shared mental processes, practices, skills, and tools which, given the right kind of coupling with individual cognition, result in constitutively (rather than just causally) extended cognitive systems. As they explain, "'cognitive institutions' consist of those practices, rules and structures that have been instituted for cognitive purposes (such as making judgments, making decisions and solving problems) in previous activities that are both cognitive and social" (Slaby & Gallagher, 2015, p. 34). Examples of "cognitive institutions" investigated include legal systems (Gallagher, 2011, 2013) and particular scientific fields such as neuroscience (Slaby & Gallagher, 2015). Central to this notion of coupling with cognitive institutions as an instance of socially extended cognition is the idea that cognitive institutions do not simply "aid" problem solving, but in fact shape the problem-space and determine what the possible solutions are: "this coupling actually makes the cognition the kind of thing that it is" (Slaby & Gallagher, 2015, p. 35). In the case of legal systems:

> Institutions of property, contracts and rights not only guide our thinking about social arrangements, for example, or about what we can and cannot do, but also allow us to think in ways that are not possible without such institutions. Insofar as we cognitively engage with such instruments and institutions we extend and transform our cognitive processes. (Slaby & Gallagher, 2015, p. 36)

And further:

> the kinds of judgments that count as legal judgments are not confined to individual brains, or even to the plurality of brains that constitute a particular

> court. They emerge in the workings of a large and complex set of pre-defined practices and are cognitive processes that further contribute to the continued working of the system in the form of precedents. (Slaby & Gallagher, 2015, p. 36)

These projects focusing on socially extended cognition, in social interaction and in coupling with cognitive institutions, further exemplify the attitudes of anti-smallism and anti-localism we have identified with extended cognition research. What these cases should make clear is how *different* the idea of extended cognition is from traditional cognitive science as well as from its immediate predecessor, behaviorism. Traditional cognitive science is internalist and focuses on particular mental (or neural) local computations, while behaviorism was externalist, concerning primarily extra-mental (or extra-neural) environmental stimuli and responses. Research on extended cognition, in contrast, takes cognition to be the dynamic adaptation of an individual to its surroundings. This means that particular instances may vary in how much they rely on the individual's own resources and on extra-personal resources; still, cognition is never isolated from perception and action, as the cognition–perception–action unit always encompasses artifacts in the environment, other individuals, and rich cultural practices that are irreducible to either objects or other individuals and what goes on inside their heads.

These promising approaches clearly go beyond the "small" and the "local", involving processes that include but are not limited to tool-use and social interaction, at multiple time and size scales and which spread out across individuals and even geographically. Taking these processes and systems to be cognitive is, as we have seen, in line with James's mark of the mental, and provide a promising *conceptual* foundation for *empirical* work—future work, but also currently productive research in extended cognition. In a comment about the reception of his work on collective remembering, Sutton and colleagues affirm:

> Theorists can continue to treat each individual's cognitive processes in isolation, as occurring solely within the head and causally triggered or cued by non-cognitive external input but we think that it will be uneconomical and unrevealing to stick to such individualist treatments of every putative case of socially distributed cognition. (Sutton et al., 2010, p. 523)

We agree and think that this claim generalizes to the extended cognition debate broadly construed. Ultimately, as we have suggested, the disagreement is not about the empirical evidence and interpretations of the evidence: what fuels the debate is researchers' radically distinct starting points, from

incompatible definitions of cognition up to widely antagonistic conceptual and methodological frameworks. We cannot, therefore, expect any sort of evidence in the near future to settle the debate, because it is not an empirical disagreement to begin with. Still, as we have seen, the historical pedigree and conceptual adequacy as well as the empirical record and promise of extended cognition gives good reason to bet on the success of work that goes against smallism and localism.

REFERENCES

Adams, F., & Aizawa, K. (2001). The bounds of cognition. *Philosophical Psychology*, *14*, 43–64.

Adams, F., & Aizawa, K. (2008). *The bounds of cognition*. Malden, MA: Blackwell Publishing.

Adams, F., & Aizawa, K. (2009). Why the mind is still in the head. In P. Robbins & M. Aydede (Eds.), *Cambridge handbook on situated cognition* (pp. 78–95). New York, NY: Cambridge University Press.

Adolph, K. E. (2008). Learning to move. *Current Directions in Psychological Science*, *17*, 213–218.

Bak, P., Tang, C., & Wiesenfeld, K. (1988). Self-organized criticality. *Physical Review* A, *38*, 364–374.

Bechtel, W., Abrahamsen, A., & Graham, G. (1999). The life of cognitive science. In W. Bechtel & G. Graham (Eds.), *A companion to cognitive science*. Malden, MA: Blackwell Publishing.

Bhalla, M., & Proffitt, D. R. (1999). Visual-motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 1076–1096.

Bongers, R. M., Michaels, C. F., & Smitsman, A. W. (2004). Variations of tool and task characteristics reveal that tool-user postures are anticipated. *Journal of Motor Behavior*, *36*, 305–315.

Burton, G. (1992). Nonvisual judgment of the crossability of path gaps. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 698–713.

Burton, G. (1993). Non-neural extensions of haptic sensitivity. *Ecological Psychology*, *5*, 105–124.

Cardinali, L., Frassinetti, F., Brozzoli, C., Urquizar, C., Roy, A. C., & Farne, A. (2009). Tool-use induces morphological updating of the body schema. *Current Biology*, *19*, R478–R479.

Chemero, A., & Silberstein, M. (2008). Defending extended cognition. In V. Sloutsky, B. Love, & K. McRae (Eds.), *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp. 129–134). New York: Psychology Press.

Chemero, A. (2009). *Radical embodied cognitive science*. Cambridge, MA: The MIT Press.

Chemero, A. (2013). Radical embodied cognitive science. *Review of General Psychology*, *17*, 145–150.

Clark, A. (1997). *Being there*. Cambridge, MA: The MIT Press.

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

Dotov, D., & Chemero, A. (2014). Breaking the perception–action cycle: Experimental phenomenology of non-sense and its implications for theories of perception and movement science. In M. Cappuccio & T. Froese (Eds.), *Enactive cognition at the edge of sense-making: Making sense of nonsense* (pp. 37–60). Palgrave Macmillan.

Favela, L., & Chemero, A. (2014). The animal-environment system. In Y. Coello & M. Fischer (Eds.), *Foundations of embodied cognition*. Psychology Press, forthcoming.

Fitzpatrick, P., Carello, C., & Turvey, M. T. (1994). Eigenvalues of the inertia tensor and exteroception by the "muscular sense". *Neuroscience*, *60*, 551–568.

Freeman, W. (2001). How brains make up their minds. New York: Columbia University Press.

Gallagher, S. (2013). The socially extended mind. *Cognitive Systems Research*, *25–26*, 4–12.

Gallagher, S. (2011). The overextended mind. *Versus: Quaderni di studi semiotici*, *113–115*, 55–66.

Gibson, J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

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

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

Jagacinski, R. J., & Flach, J. M. (2003). *Control theory for humans: Quantitative approaches to modeling performance*. Mahwah, NJ: Erlbaum.

James, W. (1890). *The principles of psychology*. Retrieved from http://psychclassics.yorku.ca/

Kugler, P. N., Kelso, J. A. S., & Turvey, M. T. (1980). Coordinative structures as dissipative structures I. Theoretical lines of convergence. In G. E. Stelmach & J. Requin (Eds.), *Tutorials in motor behavior* (pp. 3–47). Amsterdam: North-Holland.

Malek, E. A., & Wagman, J. B. (2008). Kinetic potential influences visual and remote haptic perception of affordances. *Quarterly Journal of Experimental Psychology*, *61*, 1813–1826.

Merleau-Ponty, M. (1962). *Phenomenology of perception*. London: Routledge & Kegan Paul.

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

Regia-Corte, T., & Wagman, J. B. (2008). Perception of affordances for standing on an inclined surface depends on height of centre of mass. *Experimental Brain Research*, *191*, 25–35.

Rupert, R. (2004). Challenges to the hypothesis of extended cognition. *Journal of Philosophy*, *101*, 389–428.

Rupert, R. (2009). *Cognitive systems and the extended mind*. New York: Oxford University Press.

Slaby, J., & Gallagher, S. (2015). Critical neuroscience and socially extended minds. *Theory, Culture & Society*, *32*(1), 33–59.

Sutton, J., Harris, C. B., Keil, P. G., & Barnier, A. J. (2010). The psychology of memory, extended cognition, and socially distributed remembering. *Phenomenology and the Cognitive Sciences*, *9*, 521–560. doi: 10.1007/sll097-010-9182-y

Van Orden, G., Holden, J., & Turvey, M. T. (2003). Self-organization of cognitive performance. *Journal of Experimental Psychology: General*, *132*, 331–351.

Wagman, J. B., & Taylor, K. R. (2004). Chosen-striking location and the user–tool–environment system. *Journal of Experimental Psychology: Applied*, *10*, 267–280.

Wagman, J. B., & Taylor, K. R. (2005a). Perceiving affordances for aperture crossing for the person-plus-object system. *Ecological Psychology*, *17*, 105–130.

Wagman, J. B., & Taylor, K. R. (2005b). Perceived arm posture and remote haptic perception of whether an object can be stepped over. *Journal of Motor Behavior*, *37*, 339–342.

Warren, W. H., & Whang, S. (1987). Visual guidance of walking through apertures: Body-scaled information for affordances. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 371–383.

Wilson, R. (2004). *Boundaries of the mind*. New York: Cambridge University Press.

Wilson, R., & Clark, A. (2009). How to situate cognition: Letting nature take its course. In P. Robbins & M. Aydede (Eds.), *The Cambridge handbook of situated cognition* (pp. 55–77). Cambridge: Cambridge University Press.