

## **UC Merced**

### **Proceedings of the Annual Meeting of the Cognitive Science Society**

#### **Title**

Please Explain: Radical Enactivism and its Explanatory Debt

#### **Permalink**

<https://escholarship.org/uc/item/86s219rv>

#### **Journal**

Proceedings of the Annual Meeting of the Cognitive Science Society, 39(0)

#### **Author**

Walmsley, Lachlan Douglas

#### **Publication Date**

2017

Peer reviewed

# Please Explain: Radical Enactivism and its Explanatory Debt

Lachlan Douglas Walmsley (lachlan.walmsley@anu.edu.au)

School of Philosophy, 9 Fellows Road  
Canberra, ACT 2602 Australia

## Abstract

Radical Enactivism is a position in the philosophy of cognitive science that aims to displace representationalism, the dominant position in cognitive science for the last 50-60 years. To accomplish this aim, radical enactivism must provide an alternative explanation of cognition. Radical enactivism offers two alternative explanations of cognition. The first I call the dynamical explanation and the second I call the historical explanation. The mechanists have given us reasons for doubting that the first alternative makes for a good explanation. The historical explanation does not hit the right explanatory target without the introduction of a proximate mechanism, but the proximate mechanisms suggested by radical enactivism are associationist mechanisms, the limitations of which led to the initial widespread endorsement of representationalism. Therefore, radical enactivism cannot displace representationalism in cognitive science.

**Keywords:** radical enactivism, representation, dynamical explanation, computationalism, explanation

## 1 Introduction

*Radically enactive cognition* (REC) is a position in the philosophy of cognitive science aiming to displace representationalism (Hutto & Myin 2013), the dominant position in cognitive science for the last 50-60 years.<sup>1</sup> To accomplish this aim, proponents of REC—or RECers—must settle their explanatory debt by providing us with an alternative explanation of cognition. Cognition, here, is understood in a non-question begging biological sense as that system functioning to coordinate behaviour intelligently (Godfrey-Smith 1996).<sup>2</sup> It's a familiar phenomenon. It's what happened when you wrote your last paper or organised your last workshop. It's probably what happened when you performed some less sophisticated tasks too. The RECers owes us an explanation of that. For half a century, the representational explanation of cognition has been the defining explanation of cognitive science—"the only game in town" (Fodor 1975). But the RECers argue that the representational explanation is bad. If we can't play the representation game anymore what game shall we play?

REC is committed to two alternative explanations of cognition. The first, I call the dynamical explanation. Here, RECers presuppose that all dynamical models make for good explanations, and David Kaplan and William Bechtel

have given us good reasons to think otherwise (Kaplan 2015; Kaplan & Bechtel 2011). Although many of the dynamical models appealed to by the RECers provide elegant and predictive descriptions of phenomena, they do not explain those phenomena. Their second alternative, I call the historical explanation. Although this is a good explanation, it is, by itself, not the right kind of explanation to compete with the representational explanation. Even with the addition of associationist mechanisms, the explanation still fails to explain certain intelligent behaviour, a limitation that led to the initial widespread endorsement of the representational explanation in cognitive science. Therefore, RECers owe us an explanation of cognition that can displace the representational explanation.<sup>3</sup>

## 2 The Representational Explanation

According to the representational explanation, intelligent behaviour is coordinated through the manipulation and transformation of information-bearing structures called representations. There are a number of versions of the explanation, however, owing to the different ways in which the term "representation" has been used. William Ramsey identifies four ways in which the term has been used (Ramsey 2007). Here, I defend only the representational explanation of the classical computational theory of cognition (CCTC), so only two of the four notions of representation Ramsey identifies are relevant: the *IO-notion* and *S-representation*. For brevity's sake, I will discuss only the IO-notion (Ramsey 2007: 68-77).<sup>4</sup>

The IO-notion of representation is used to describe those situations in which some structure standing in for another is taken as a system's input (hence the "I") and transformed into another structure (again standing in for yet another structure), which is its output (hence the "O"). If this is a little abstract, imagine a calculator taking as input some structures standing in for numbers and mathematical operators—say, "2," "3," "+," and "=" All going well, the calculator transforms its input into another structure, "5," which stands in for the number five, and which the

<sup>3</sup> There is another class of alternatives to the representational explanation as I characterize it in §2, which I call cognitive-neuroscience explanations. REC does not offer these explanations so they won't be considered here. Relating the representational explanation to these alternatives will be left for future work.

<sup>4</sup> CCTC can be made more rigorous with any number of formal theories of computation. Here, I follow Gallistel and King's and assume a functioning homomorphism view of computation and the Turing machine mathematical formalism because these apply to the desert ant example in section 4.1 (see Gallistel & King 2009: 196-206).

<sup>1</sup> Radical enactivism is just one position in the greater anti-representationalist movement in the philosophy of cognitive science. Less ambitious positions within this movement will not be discussed in this paper.

<sup>2</sup> This understanding does not presuppose that cognition must be explained by appealing to representation.

calculator gives as its output. Here's another example. Imagine a face recognising computer. Again, its input is a structure standing in for another structure, a face in this case. Let's say its input is a portrait of Charles Darwin. All going well, the computer transforms its input and gives as output a different structure that stands in for the individual to whom the face belongs. Something like "Charles Darwin." CCTC models the transformation of a structure from input to output as a series of operations carried out by component sub-systems. Each sub-system also takes as its input structures standing in for other structures and gives as its output yet more such structures. It is due to this on-going replacement and its role in the transformation of system input to system output that CCTC takes such systems to manipulate and transform structures standing in for other structures—that is, representations.<sup>5</sup>

If you are sceptical of CCTC's representational explanation then consider the digital computer. The digital computer can perform calculation and facial recognition as in the examples above and does so in the way I've described. The digital computer is a paradigm case of a physical system for which the representational explanation is good. It is, in effect, an existence proof for good representational explanations. No matter what position you occupy in the philosophy of cognitive science, if it follows from your argument that the representational explanation of a digital computer is bad, then that is a *reductio* against your argument. Whether or not the representational explanation is good for human cognition is an empirical question. But RECers argue that the representational explanation of human cognition is bad on theoretical grounds.

## 2.1 The Cost of the Representational Explanation

RECers claim that we should reject the representational explanation because it is too metaphysically demanding to be naturalised.<sup>6</sup> A naturalistic explanation, here, is understood as one that can be squared with our current scientific knowledge—no spooky stuff. The representational explanation is too metaphysically demanding, REC claims, because it posits the existence of *content*, which determines what a structure stands for: the structure "5" stands in for the number five because of its content. According to REC, no naturalistic account of content has succeeded in explaining the "special properties," such as "truth, reference, implication," attributed to content (Hutto & Myin 2013: 67). These properties make content, and hence the

representational explanation, "too metaphysically extravagant to be accepted by hard-nosed naturalists" (21).

As a naturalist, I shy away from metaphysical extravagance, and I agree that no naturalistic account of representation has explained content as REC understands it. But I resist the assumption that content must have such metaphysically demanding properties, such as truth and reference. One reason why REC might make this assumption is because their emphasis is partly on mentality and the mind: "Enactivism is inspired by the insight that the embedded and embodied activity of living beings provides the right model of understanding *minds*" (Hutto & Myin 2013: 4, my emphasis). The focus of the representational explanation radical enactivists hope to displace, however, is not on the mind but on cognition. It may prove difficult to give good naturalistic explanations of the mind's features because the mind simply doesn't lend itself to good naturalistic explanation. But I will leave that to the philosophers of mind.

Can we make do with less metaphysically demanding accounts of representational in cognitive science? I think we can. Furthermore, I think REC must also make do with less metaphysically demanding accounts of representation because they are committed to the existence of public representational systems, such as public language. How does "5" come to stand in for (at least in most instances) the number five in our public language? Radical enactivists cannot answer that "5" stands for the number five because of representations internal to the language users. The meaning of public representations can't be due to something metaphysically extravagant in your head or in mine. Such an answer is anathema to RECers. Instead, public structures like "5" come to stand in for what they do in virtue of the interactions between public language users (Hutto 2008). This was, roughly, Wittgenstein's view of language in his *Philosophical Investigations*. According to this view, "5" stands in for the number five because we use that structure, either as a written symbol or as an utterance, in those situations involving five-type things, such as when we ask someone to fetch five stones or to wait five days. Over time, language users become expert at recognising situations like these and can use "5" in situations involving much more complicated or abstract entities, like dollars and electrons. For Wittgenstein, structures stand in for other structures (in most cases) in virtue of their functional role in a system of public language users. In slogan form: "the meaning of a word is its use in the language" (Wittgenstein 2009/1953: §43). So "5" or "five" means (has as its content) the number five because of the way in which "5" is used in a community of language users.<sup>7</sup>

REC is committed to something like Wittgenstein's meaning-as-use account. A metaphysically undemanding explanation of representation such as this can generalise to cognitive systems. Just as utterances can be said to stand in for other structures in virtue of their functional role in a

---

<sup>5</sup> This is a minimal conception of CCTC. Many classical computationalists, such as Jerry Fodor (1975), endorse a language of thought, but CCTC is compatible with the absence of a language of thought. Furthermore, CCTC need not (and I think should not) posit anything like that found in our folk psychological theories (Stich 1983).

<sup>6</sup> This is not the only reason RECers have for rejecting representations. For example, another reason, which I deal with below, concerns the causal efficacy of semantic properties. For brevity's sake I can present no more reasons here.

---

<sup>7</sup> This is only a sketch of Wittgenstein's view, but a sketch will do here.

public system, so can structures in a computational system. These structures can be said to stand in for others in virtue of how they are passed between the different sub-systems of the computational system and how they are transformed by each sub-system—that is, how they are used within and by the system. You might be sceptical of a Wittgenstein-flavoured meaning-as-use account of representation. And it's fine if you are. All that's important here is that REC is committed to an explanation of interactions between organisms—that is, human public practices—that involves representation and avoids metaphysical extravagance. If public practice can be given a metaphysically undemanding representational explanation then so can cognition. There is no reason to suppose that representational explanations of intraorganism processes will be any more metaphysically extravagant than those for interorganism processes.

Advancing the representational explanation, at least as it is understood in CCTC, does not entail positing anything as problematic as REC suggests it does. As I outlined above, within CCTC we can posit representations and explain representational content in virtue of a structure's function within the computational system. A structure stands in for what it does because of the role that structure plays in the computational system. Furthermore, this way of grounding content is analogous to REC's strategy for grounding the content of public representations. So, if REC remains sceptical of CCTC's representational explanation, as I have outlined it in this section, then they must rethink their own commitments to the existence of public representational systems.

Furthermore, according to CCTC's representational explanation, structures in a computational system are not causally efficacious because of their content. They are causally efficacious because of how their formal properties map onto physical parts of the target system, such as transistors or neurons (Fodor 1981; Pylyshyn 1984; Gallistel and King 2009). If the RECers suppose the representational explanation requires that structures be causally efficacious because of their content then they are setting up a straw person. Hence, I take it this is not their position. If the RECers accept CCTC's representational explanation but reject other versions of the representational explanation, such as those according to which structures *are* causally efficacious in virtue of their content, then they are conservatives, classical computationalists rather than radicals. Hence, I take it this is not their position. Instead, I take it that REC is a position according to which CCTC's representational explanation is unnecessary for explaining any intelligent behaviour. This is an empirical question. And we have good reasons to answer it in favour of the representational explanation (see §4.1 especially). From here on, I argue that REC's candidate replacement explanations are not genuine alternatives to the representational explanation of CCTC or, where they are genuine alternatives, they fail to explain some intelligent behaviour that the representational explanation can.

### 3 The Dynamical Explanation

The first alternative to the representational explanation offered by REC is the dynamical explanation: “the vast sea of what humans do and experience is best understood by appealing to dynamically unfolding, situated embodied interactions and engagements with worldly offerings” (Hutto & Myin 2013: ix). Dynamical explanations are constructed with the language of dynamical systems theory, which models how physical systems change over time with differential and difference equations. These equations quickly become analytically intractable as structures or details are added but their solutions can be satisfactorily approximated using numerical methods and computer simulation. From the approximate solutions, modellers create geometric visualisations of the different ways in which the system can change over time as transitions through a state space. The explanation's language is complex, but it need not concern us here. The problem with dynamical explanations is not the language in which they are described.

A paradigm case of a dynamical model is the Haken-Kelso-Bunz (HKB) model of human hand movements (Haken *et al.* 1985). The model captures “voluntary oscillatory motions of the two index fingers”—that is, the movement of your index fingers when you move them back and forth in a coordinated fashion, either symmetrically or asymmetrically. In particular, it captures the abrupt change from asymmetrical and symmetrical coordination when the oscillations reach a certain frequency. HKB is a phenomenological model, built to have a close qualitative fit with the system's behaviour: the “first step in the development of the model is to provide a mathematically accurate description of the main qualitative features of the data” (349).

HKB has received much attention because it is a minimal model of a “relatively simple two-component system” (Bressler & Kelso 2001: 28) with predictive power, capturing the dynamics of a wide range of interactions including those between an agent and their environment (Kelso 1994) and between two agents (Schmidt *et al.* 1990). For RECers and similarly inclined anti-representationalists, models like this provide good alternative explanations because they make simple and generalisable predictions (without positing content): “If models are accurate enough to describe observed phenomena and to predict what would have happened had circumstances been different, they are sufficient as explanations” (Chemero & Silberstein 2008: 12). Although accurately describing the behaviour of a large class of systems is a virtue of these models, good descriptions and predictions are not sufficient for explanation.

Dynamical explanations of the intelligent coordination of behaviour can only be genuine alternatives to the representational explanation if they are *genuine explanations*. Dynamical explanations are only genuine explanations if the predictions and descriptions of behaviour offered by models like HKB are also explanatory.

Description and prediction are certainly similar to explanations. The covering law account of explanation, for example, treats them as having the “same logical character” as each other (Hempel 1958: 37; 1965). But they are importantly different from explanation (Kaplan 2015; Kaplan & Bechtel 2011). The difference between description and explanation is obvious: a description of a phenomenon is simply a statement of the explanandum. The difference between prediction and explanation is not so obvious but just as real.

To see the difference between prediction and explanation, imagine a flagpole, which casts a shadow as the sun rises and sets. As the position of the sun changes, so does the shape and size of the shadow. The two change together with law-like regularity. Hence, we can use the height of the flagpole along with the position of the sun and some mathematics to predict the shape and size of the shadow. We can also use the shape and size of the shadow along with the position of the sun and some mathematics to predict the height of the flagpole, but we cannot explain the height of the flagpole in virtue of the shadow’s shape and size. Although predictions can run either way, from flagpole to shadow and from shadow to flagpole, explanations run in only one direction—in this case, from flagpole to shadow (Bromberg 1966; also Kaplan & Bechtel 2011: 440-441). Explanations must inform us of that which gives rise to a phenomenon, so an explanation of the height of the flagpole would appeal to the factory in which it was made, but not to its shadow.

Precise mathematical models of behaviour like HKB are not the explanans.<sup>8</sup> They are the explanandum. This is not especially controversial; dynamical modellers themselves are aware of this. Haken et al., for example, admit of their model that it describes the coupling between the two hands but says nothing about what gave rise to that coupling and leave this for “further theoretical and experimental research” (Haken et al. 1985: 355). Short an actual explanation of the phenomena described by HKB, Haken et al. provide a how-possible explanation, describing a mechanism that might be responsible for causing the phenomena: “one coupling might be established via the corpus callosum, the well-known band of fibres that joins the two hemispheres of the brain” (*ibid.*). Another explanation of the regularities described by dynamical models like HKB may involve the manipulation and transformation of information-bearing structures. The behaviour of digital computers, for example, can be modelled using the tools of dynamical systems theory, but, as I said above, it is a paradigm case of a system for which the representational explanation is good. Hence, dynamical models of cognition—explanatory or not—are compatible with representational explanations. Even if

---

<sup>8</sup> As Kaplan (2015) argues, dynamical models can be explanatory when construed as representing the dynamics of the mechanism responsible for the phenomena to be explained, but not when they are merely phenomenological. In these cases, the mechanism and not just its dynamic behaviour constitute the explanation.

REC’s dynamical explanation were genuinely explanatory it would be compatible with representational explanation.

#### 4 The Historical Explanation

REC’s second alternative to the representational explanation is the historical explanation. In this case, cognition is explained in virtue of an agent’s “history of previous engagements and not in some set of internally stored mental rules and representations” (Hutto & Myin 2013: 9). To make this concrete, imagine some behaviour:

“Someone is living in a house with a kitchen in the hallway, such that she has to walk around a sideboard to get to the other side. Suppose that at some point the sideboard gets removed, but that the person still takes the same curve to get to the other side of the hall.” (Degenaar & Myin 2014: 3642)

Here is the historical explanation of that behaviour:

“In the new situation, the person is going through the same old motions in absence of the environmental basis for these motions. Over the years, a behavioural pattern has emerged: the person tends to take a particular trajectory when walking through the hallway.” (Degenaar & Myin 2014: 3642)

The historical explanation is neither mere prediction nor description. Unlike REC’s first alternative explanation, its second is genuinely explanatory. However, it is still not a genuine alternative to the representational explanation. Rather, it is compatible with the representational explanation. As Jan Degenaar and Erik Myin say of the above example, “This might involve representations or it might not” (Degenaar & Myin 2014: 3642).

The historical explanation is not the right kind of explanation to be an alternative to the representational explanation because the historical explanation is an ultimate explanation, while CCTC’s representational explanation is a proximate explanation. Niko Tinbergen (1963) first made the distinction between proximate and ultimate explanations. An example will help illustrate the distinction: humans regularly help needy others at a cost to themselves. One explanation of this behaviour is that empathising with needy others motivates us to help them (Batson 2011). This is a proximate explanation. It tells you about the mechanism here and now—empathy—that produces the helping behaviour. But why this sort of mechanism? Why are we empathetic? This question calls for an ultimate explanation, which might explain the helping behaviour as the result of selection for a particular behavioural disposition in terms of benefits to an organism or group’s fitness. For example, perhaps our empathetic ancestors were better carers for their and their kin’s young, so our empathetic ancestors did better than our nonempathetic ones and empathy spread through the population (De Waal 2008). Importantly, ultimate explanations need not refer to evolution. They can also refer to an agent’s developmental history (Baum 1994). For example, an ultimate explanation of an agent *without* the

disposition to help may be that their helping was rewarded materially early in their developmental history such that the agent came to expect material rewards to follow from helping (Warnken & Tomasello 2014). Hence, when there are no material rewards on the horizon, the agent doesn't help. Here, our ultimate explanation refers to a learning process rather than an evolutionary one.

Proximate and ultimate explanations are natural partners, with one explaining the mechanism producing the behaviour here and now and the other explaining why that kind of mechanism exists instead of another. Since REC's historical explanation is compatible with the representational explanation it is no real alternative at all.

#### 4.1 The Proximate Explanation

RECs might respond that their historical explanation does involve a proximate mechanism, which is something akin to what Kim Sterelny (2003) calls a detection system. Detection systems link certain environmental stimuli with certain behavioural responses and do not involve the manipulation and transformation of information-bearing structures.<sup>9</sup> In the example above, entering the hallway has been linked with the response of taking a particular trajectory. This connection has been wired up through something like simple association-based learning—the hallway becomes associated with taking the trajectory in virtue of certain rewards, such as not bumping into the sideboard. But detection systems can also be wired up through evolutionary processes. Organisms can be born responding to particular stimuli with particular responses because such organisms have had greater reproductive success. The infamous male *Photuris* firefly, for example, is born with such a detection system, which links a certain series of flashes with the response of flying toward the source of the flashes. Female *Photuris* fireflies produce these flashes and males find them, so the two can mate.

Although often effective, detection systems are fragile. The *Photinus* firefly's detection system is exploited by the *Photuris* firefly. They produce the flashing just like the *Photinus* females, catching and eating a fair number of unfortunate males (Lloyd 1965). Sterelny's robust systems are, as the name suggests, less fragile than detection systems. These link a number of environmental stimuli with a particular response. But even these have their limits. Once the causal chain through which a relevant aspect of an environment and an appropriate behavioural response are linked becomes sufficiently complex and rare, it becomes invisible to whatever processes build detection and robust systems, such as associationist learning or evolution by selection. Sterelny argues that this is the case in complex social environments in which deception is common and multi-place relations between group members matter, and from which language can emerge as it has in the case of human lineage. Explaining human cognition, then, will

---

<sup>9</sup> Some might want to resist this claim and argue that detection systems do involve information-bearing structures. For good reasons to not to resist see (Ramsey 2007).

require a proximate explanation appealing to more than detection systems and associationist learning.

If the only good proximate explanation RECs have up their sleeves is one involving associationist mechanisms linking a stimulus with response in virtue of a history of interaction then that's a problem. As Sterelny argues, the complexities of social life are such that stimulus-response systems like *Photinus*'s just won't do. But REC needs more than a good proximate explanation for human social behaviour (here, RECs will argue is richly scaffolded by shared practices and hence not as computationally demanding as it seems). REC also needs one for the behaviour of much simpler organisms, such as insects (Gallistel 1990, Gallistel & King 2009). Desert ants, among other insects, often trace winding paths away from their nests as they forage. Upon returning to their nests, they don't retrace their steps, but take an almost direct route. This is known as path integration or dead reckoning. It requires integrating information both about the distance and direction travelled from the nest. This ability has been experimentally demonstrated (Wehner & Srinivasan 1981). In Wehner and Srinivasan's experiment, ants forage from their nest to a feeder station 20m away. Upon reaching the feeder station, the ants are transferred to a test area several hundred meters away with a replica feeder station. From this replica, the ants take a direct path to where their nest should be. When they reach this point they begin searching for their nest in different directions. In these experiments, the ants are clearly not using environmental cues. If they were, they would find their actual nest, not where their nest should be. Their destination is a novel location, so they cannot be navigating by anything like habit. In this instance, there is no history of on-going interactions to appeal to and no stable environmental stimuli with which behaviour can be associated. A good explanation is one positing a computational process involving representations of the ants' location relative to the nest and feeder station.

#### 5 Revolution?

The radical enactivists owe me an explanation. They owe you one too. They owe us all an explanation of how biological systems like you and I behave in the complicated ways we do. They owe us an explanation of cognition. Importantly, the explanation cannot one of those advanced before the cognitive revolution. You cannot displace the representational explanation with stimulus-response mechanisms because the representational explanation initially gained traction in virtue of the limitations of such mechanisms.

So what new explanations are on offer? There is the dynamical explanation, according to which our actions are the results of dynamically unfolding interactions with our environments. But what explains why these dynamics obtain instead of others? When I become reciprocally coupled with my environment, what initiates and maintains that coupling such that my behaviour can be predicted with a set of elegant differential equations? Although the models of the

dynamical explanation can offer mathematically precise descriptions of behaviour, they don't explain why those descriptions hold. If those in the radical camp want an anti-representational revolution, they must fill the explanatory gap left by the representational explanation. So far, they have failed to do this.

### Acknowledgments

Thank you to Ronald Planer and David Kalkman for their comments on drafts of this paper. Thank you also to three anonymous reviewers whose comments were both fair and insightful. Funding was provided by Australian Research Council (Grant No. ARC FL13).

### References

- Batson, C. D. (2011). *Altruism in humans*. Oxford: Oxford University Press.
- Baum, W. M. (1994). *Understanding behaviorism: Science, behavior, and culture*. New York: Harpercollins College Division.
- Bressler, S. L. & Kelso, J. A. S. (2001). Cortical coordination dynamics and cognition. *Trends in cognitive science*, 5, 26-36.
- Bromberger, S. (1966). Why questions. In R. G. Colodney (ed.). *Mind and Cosmos*. Pittsburgh, PA: University of Pittsburgh Press.
- Chemero, A. & Silberstein, M. (2008). After the philosophy of mind: replacing scholasticism with science. *Philosophy of Science*, 75, 1-27.
- De Waal, F. B. M. (2008). Putting the altruism back into altruism: the evolution of empathy. *Annual Review of Psychology*, 59, 279-300.
- Degenaar, J. & Myin, E. (2014). Representation-hunger reconsidered. *Synthese*, 191, 3639-3648.
- Fodor, J. A. (1975). *The Language of Thought*, Cambridge, MA: Harvard University Press.
- Fodor, J. A. (1981). *Representations*. Cambridge, MA: MIT Press.
- Gallistel, C. R. & King, A. (2009). *Memory and the Computational Brain*. Malden: Wiley-Blackwell.
- Godfrey-Smith, P. (1996). *Complexity and the Function of Mind in Nature*. Cambridge: Cambridge University Press.
- Haken, H., Kelso, J. A. S., & Bunz, H. (1985). "A theoretical model of phase transitions in human hand movements," *Biological Cybernetics*, 51, 347-356.
- Hempel, C. G. (1958). The theoretician's dilemma: A study in the logic of theory construction. *Minnesota Studies in the Philosophy of Science*, 2, 173-226.
- Hempel, C. G. (1965). Aspects of scientific explanation. *Aspects of Scientific Explanation; And other Essays in the Philosophy of Science*. New York: The Free Press.
- Hutto, D. D. (2008). *Folk Psychological Narratives: The Sociocultural Basis of Understanding Reasons*. Cambridge, MA: MIT Press.
- Hutto, D. D. & Myin, M. (2013). *Radicalizing Enactivism: Basic Minds Without Content*. Cambridge, MA: MIT Press.
- Kaplan, D. M. (2015). Moving parts: the natural alliance between dynamical and mechanistic modeling approaches. *Biology & Philosophy*, 30, 757-786.
- Kaplan, D. M. & Bechtel, W. (2011). Dynamical models: an alternative or complement to mechanistic explanations? *Topics in Cognitive Science*, 3, 438-444.
- Kelso, J. A. S. (1994). Elementary coordination dynamics. In S. P. Swinnen, H. Heuer, J. Massion, & P. Casaer (eds.). *Interlimb Coordination: Neural, Dynamical, and Cognitive Constraints*. San Diego: Academic Press: 301-318.
- Lloyd, J. E. (1965). Aggressive mimicry in *Photuris*: firefly femmes fatales. *Science*, 149, 653-654.
- Pylyshyn, Z. (1984). *Computation and Cognition*. Cambridge, MA: MIT Press.
- Ramsey, W. M. (2007). *Representation Reconsidered*. Cambridge: Cambridge University Press.
- Schmidt, R. C., Carello, C., & Turvey, M. T. (1990). Phase transitions and critical fluctuations in the visual coordination of rhythmic movements between people. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 227.
- Sterelny, K. (2003). *Thought in a Hostile World: The Evolution of Human Cognition*. Malden: Blackwell Publishing.
- Stich, S. P. (1983). *From Folk Psychology to Cognitive Science: The Case Against Belief*. Cambridge, MA: MIT Press.
- Tinbergen, N. (1963). On aims and methods of ethology. *Zeitschrift für Tierpsychologie*, 20, 410-433.
- Warneken, F. & Tomasello, M. (2014). Extrinsic rewards undermine altruistic tendencies in 20-month-olds. *Motivation Science*, 1, 43-48.
- behaviour of desert ants, genus *Cataglyphis* (Formicidae, Hymenoptera). *Journal of Comparative Physiology*, 142, 315-338.
- Wittgenstein, L. (2009/1953). *Philosophical Investigations*. Trans. G. E. M. Anscombe, P. M. S. Hacker, & J. Schulte. 4th ed. Malden: Wiley-Blackwell.