Ergo AN OPEN ACCESS JOURNAL OF PHILOSOPHY

Embodied Cognition and the Grip of Computational Metaphors

KATE FINLEY
Hope College

Embodied Cognition holds that bodily (e.g. sensorimotor) states and processes are *directly* involved in some higher-level cognitive functions (e.g. reasoning). This challenges traditional views of cognition according to which bodily states and processes are, at most, *indirectly* involved in higher-level cognition. Although some elements of Embodied Cognition have been integrated into mainstream cognitive science, others still face adamant resistance. In this paper, rather than straightforwardly defend Embodied Cognition against specific objections I will do the following. First, I will present a concise account of embodied conceptual processing and highlight some of its advantages over non-embodied accounts, with a specific focus on the role of metaphors. Second, I will detail the influence of computational metaphors on theories of cognition and their effect on the evaluation of these theories. Third, I will argue that embodied cognitive mechanisms, specifically those operating through computational metaphors, may drive some of the resistance to Embodied Cognition—and that Embodied Cognition is able to offer a uniquely compelling account of this. Ultimately, this will contribute to an improved understanding of Embodied Cognition, its explanatory power, and how it ought to be evaluated. Additionally, it will shed light on the role of metaphors in shaping philosophical thought and highlight the importance of these influences.

Keywords: Embodied Cognition; Computationalism; Concepts; Metaphor; Computer; Mind

1. Introduction

Embodied Cognition theories are often contrasted with Computationalism, specifically classical Computationalism—so I will use the latter as a foil for the former in order to clarify some of the key claims of mainstream theories of

Contact: Kate Finley <finley@hope.edu>

https://doi.org/10.3998/ergo.7136

Embodied Cognition. I begin by sketching key distinctions between Embodied and classical Computationalist theories of cognition—specifically, how they understand representation and conceptual processing. In addressing Embodied Cognition, I focus on the role of embodied metaphors in conceptual processing. I then turn to focus on the potential impact of computational metaphors on thinking about cognition—arguing that many statements invoking Computationalism are indeed metaphorical, and the metaphors they draw upon are both 'conceptual' and 'embodied' metaphors.[1] Finally, I specify the potential effects of computational metaphors, tracing specific examples, and articulate the upshots for how we ought to evaluate embodied theories of cognition.

A few brief notes before continuing. First, I will follow the use of 'concept' and 'conceptual processing' found in psychological, rather than philosophical, literature. So, by 'concept' I simply mean something which 'stands in for' or 'points to' something else—a generalized description formed on the basis of particular instantiations. This enables me to remain neutral between representationalist and non-representationalist accounts of conceptual processing. Second, although Embodied Cognition theories address the involvement of a range of bodily states and processes in cognition, including those involved in perception, motor feedback, interoception, and emotion—I focus solely on those involved in sensory and motor feedback—and thus refer to 'sensorimotor states and processes' rather than 'bodily states and processes' in what follows. Furthermore, I understand 'sensorimotor states and processes' to include non-neural states and processes, such as those receiving sensory input involved in perceptual and motor experiences; as well as the lower-level neural states and processes that are involved in processing these experiences and simulations of these experiences (such as those that occur in the visual cortex). In contrast, I will use 'mental states and processes' to refer only to higher-level neural states and processes—such as those involved in processes like abstraction and reasoning. Thus, for my purposes, the key claim of Embodied Cognition is that sensorimotor states and processes are directly involved in cognition.[2]

1. I will address what I mean by 'conceptual metaphors' and 'embodied metaphors' in more detail below.

2. Note that restricting the discussion of "mental states and processes" to higher-level neural states and processes has the key consequence that what counts as minded or mental is a more limited, non-ubiquitous notion that occurs only in animals with nervous systems of a certain degree of complexity.

2. Theories of Cognition & Conceptual Processing

Computationalism originated in the 1960s and holds, roughly, that the brain or mind is (like) a computer and cognition is (like) computation (Fodor 1980; Haugeland 1981; Holyoak 2001).[3] More specifically, *Classical Computationalism* picks out a set of theories that hold that cognition and conceptual processing consist solely of intentional mental representations and our relations to them. According to Classical Computationalists, concepts are *wholly mental* in that they are solely instantiated by mental states, and sensorimotor states and processes can only be involved indirectly.[4] Mental processes abstract information from sensorimotor experiences and transduce it into a kind of mental language, thereby enabling it to inform mental representations. In other words, Classical Computationalism adds to the foundational claims of Computationalism claims about the nature of the representations that cognitive processes operate over.[5] The resulting mental representations are then largely propositionally or linguistically structured. Thus, a mental representation is a *symbolic representation:* it does not resemble what it represents physically or functionally—and it is both *amodal* (not tied to a particular modality or set of modalities) and *context-independent.* In addition to providing input, bodily states and processes may also *modulate the capacity* of some mental processes to perform certain cognitive functions: increasing, decreasing, or completely eliminating certain capacities. Although in both cases of providing input and modulating capacity, bodily states and processes impact cognition, they do so only *indirectly* as they impact the mental states and processes which themselves carry out the cognitive functions.[6]

In contrast, *Embodied Cognition* theories hold that sensorimotor states and processes are *directly* involved in cognition—as opposed to only mental states being directly involved and sensorimotor states being at most, indirectly involved. Although there are many potentially fruitful ways to differentiate between specific Embodied Cognition theories, it is sufficient for my purposes to sketch some

3. Notably, there is significant heterogeneity among theorists, with some relying heavily on the notion that the *mind* is a computer, while others specify that the *brain* is a computer. I will address both below.

4. There is disagreement among Representationalists over which brain regions are involved in things like semantic processing; however, all of the proposed brain regions are involved in 'mental states and processes' according to my previous distinction. For a proposal of a single 'hub' for semantic processing see Binder & Desai (2011) and for proposals involving multiple regions see Patterson et al. (2007) and Bookheimer (2002).

5. Although there are many different, nuanced theories of Computationalism, sketching some of the key claims of Classical Computationalism regarding representations and conceptual processing will be sufficient for my purposes.

6. Below I will further distinguish between two different kinds of Computationalism, but this broad-strokes version is sufficient for now.

central tenets of mainstream accounts.[7] To do so, we must distinguish mainstream Embodied Cognition from its more radical counterparts—such as Enactivism and Gibsonian Ecological Psychology which see mental representations as "an empty and misguided notion" and conceptual processing as involving *nothing but* sensorimotor processing (Goldinger et al., 2016).[8] Lawrence Barsalou notes that mainstream Embodied Cognition has been consistently misunderstood as sharing this more radical view of conceptual processing. In response, he notes that it has "been clear for some time that our group [of Embodied Cognition theorists] views abstract [mental] representations as essential." (2016, 1124).[9]

Thus, mainstream Embodied Cognition can be seen as a kind of Representationalist theory—agreeing with Classical Computationalism that mental representations play an essential role in conceptual processing contra non-Representationalist radical Embodied Cognition theories.[10] However, mainstream Embodied Cognition agrees with its more radical counterparts that sensorimotor states and processes also play an essential role in concepts and conceptual processing contra Classical Computationalism. Mainstream Embodied Cognition thus holds that both mental *and* sensorimotor states and processes are directly involved in cognition, and specifically, in conceptual processing.[11]

I will also bracket disagreement over the specific nature of dependence involved in direct vs. indirect sensorimotor involvement in cognition and here illustrate the notion of *direct involvement* that I will be dealing with through the notion of *embodied concepts* which are concepts that are at least partially instantiated in, or constituted by, sensorimotor states and processes. Some of the most compelling accounts posit that this occurs through *neural reuse*: a phenomenon

7. Theories differ in their focus on specific *kinds of dependence* of cognition on the body: see Wilson and Foglia (2017) who distinguish between theories according to which the body acts as either a constraint on, distributor of, or a regulator of cognition. Theories also differ in *the aspects of cognition* that they claim the body affects: see Shapiro (2010) who distinguishes Embodied Cognition theories which focus on how the body *affects conceptualization* in cognition (the construction and maintenance of concepts), from those that focus on the body's role in *replacing computational and representational aspects* of cognition, and those that focus on aspects of the body that serve as *constituents* of cognition itself.

8. These more radical versions of Embodied Cognition include theories like Enactivism (Hutto & Myin 2017; Gallagher 2017) and Gibsonian Ecological Psychology (Chemero 2011; Wilson & Golonka 2013).

9. This group of mainstream Embodied Cognition theorists also includes Andy Clark (2008).

10. Thus, while some use 'Computationalism' interchangeably with 'Representationalism', I will distinguish between the two. Additionally, while there is disagreement over whether all representations are in some sense conceptual, I do not need to take a stance on that question. It is enough that *some* or even *most* of cognition consists of representation, and that much of representation is conceptual.

11. Furthermore, the balance of sensorimotor and mental states and processes involved in particular concepts likely varies. For an overview of integration proposals see Pulvermüller (2013).

in which regions of the brain established or typically associated with one function (in this case, regions performing sensorimotor functions) are exploited to perform additional (in this case, cognitive) functions without losing their ability to perform their original function(s) (Anderson 2010; 2014; Pulvermüller 2018).[12] One neural reuse-based account of conceptual processing is *Semantic Embodiment,* according to which accessing embodied concepts involves the reactivation of systems involved in relevant sensorimotor experiences (Barsalou 2003a; 2009; 2016). As Barsalou explains,

> modality-specific information is represented conceptually by partially reusing the same brain areas that represent this information during perception and action. Thus, representing color and taste features conceptually requires reusing some of the same systems active during vision and eating…reusing a modality-specific pathway during conceptual processing simulates the kind of processing that this pathway performs during perception, action, and/or internal states. (2016, 1130)

So, according to this account, simulations are a crucial part of at least some concepts. For example, APPLE might be partially constituted by simulations of perceptual (visual, tactile, gustatory) experiences of apples.[13] Importantly, research suggests that in many instances, these sensorimotor simulations occur within the timeframe spanning the comprehension process——which suggests that the simulation is not merely *associated with* the relevant concept (and thereby only indirectly involved in conceptual processing) but rather is *a part of the concept* itself (Pulvermüller 2013).[14] Additional research further supports this by demonstrating the impoverishment of concepts in the absence of relevant sensorimotor experiences or simulations (Brookes & Etkina 2009; 2015; Goldin-Meadow *et al.* 2009; Jeppsson *et al.* 2013; Lakoff and Nunez 2000; Nemirovsky *et al.* 2012).

According to Barsalou (2003a; 2003b), more abstract concepts like FRUIT may be grounded in these more concrete concepts like APPLE. In such cases, the

12. Note that Anderson (2010; 2014; 2016) and Raja & Anderson (2019) draw on neural reuse research to support a less representation-friendly version of Embodied Cognition.

13. I will use SMALL-CAPS to indicate reference to concepts. Also, note that these simulations most often occur subconsciously, and so may not impact the phenomenal character of conceptual processing.

14. As Pulvermüller explains, "Crucially, precise mapping in time using magnetoencephalography (MEG) showed that the brain correlates of abstract idiomaticity and those of action-grounded constituent word meaning occurred at the same time, at 150–200 ms after [the stimuli]… These results further confirm early semantic activations with the same latency in sensorimotor and multimodal cortices, and argue against the possibility that sensorimotor semantic activation might be an epiphenomenon, just following after, or spilling over from, semantic system activation elsewhere." (2013: 467).

abstract concept is partially constituted, in a sense, by more concrete concepts, and thus, at least part of what it is to 'activate' the more abstract concept is just to 'activate' the more concrete component concepts.[15] Consequently, the embodied elements of the component concepts also serve as embodied elements of the concept that they compose. So, FRUIT may be partially constituted by component concepts like APPLE and ORANGE, which themselves are partially constituted by simulations of perceptual processes involved in (visual, tactile, and gustatory) experiences of apples and oranges. So, neural reuse occurs in that one's FRUIT concept is partially constituted by one's past perceptual experiences of specific fruits.

Semantic Embodiment can also be used to provide a compelling account of the embodiment of more abstract concepts that do not semantically overlap with component concepts, like FRIENDSHIP in metaphors that map friendship or relational closeness onto physical experiences of warmth (i.e. she has a warm personality, etc.). Such concepts are again grounded in more concrete concepts and their component sensorimotor states and processes, this time through metaphorical mapping. This account draws on *Conceptual Metaphor Theory* (CMT), according to which people often understand many cognitive domains through the use of conceptual metaphors which are "automatic, ubiquitous conceptual device[s] that enables us to think of less familiar and more abstract things in terms of more familiar and concrete things" (Finsen et al. 2019).[16]

Notably, while Lakoff (1993: 244) maintains that "metaphor is fundamentally conceptual, not linguistic, in nature, …the overwhelming majority of evidence for conceptual metaphor is linguistic in nature" (Casasanto 2009: 127). In other words, the presence of linguistic metaphors in communication about a topic (e.g. "brains are computers") often indicate the presence of underlying conceptual metaphors (e.g. thinking about brains (to some extent) in terms of computers).

According to CMT, a conceptual metaphor results from cross-domain mapping in which a "target" concept from a more abstract domain is "mapped onto" a "source" (or "base") concept from a more concrete domain. These metaphors enable us to understand less familiar, more abstract concepts by connecting them to more familiar concepts that are often more concrete and perceptually-grounded. These domain pairings reflect the "correlation learning principle" according to which "neurons that fire together wire together" and often come about as a result of experience, rather than inherent similarities between them.[17]

15. One may activate a concept by reading it, speaking about it, or otherwise calling it to mind.

16. See also Gibbs (2011), Gibbs & Matlock (2008), Kövecses (2008), and Lakoff & Johnson (2008).

17. This phrase is often mistakenly thought to derive from a quotation from Hebb 1949, but instead comes from the quote "cells that fire together wire together" (Shatz, 1992, p. 64).

Thus, because the target concept has been "mapped" onto the source concept, when a target concept in a metaphor is activated, so too is the source concept. And when the source concept is itself embodied, and thus partially constituted by simulations of relevant sensorimotor states and processes, so too is the target concept which has been mapped onto it. For example, hearing phrases such as "she grasped the idea" and "he is sweet" which invoke metaphors, sensorimotor simulations activating the motor cortex gustatory areas of the brain were activated (Boulenger et al. 2012; Citron & Goldberg 2014).

See the diagram below (Figure 1) for the three kinds of Semantic Embodiment accounts detailed in this section. The relevant concepts are represented by boxes within which are mental states and processes as well as sensorimotor states and processes (represented by the cloud shape), which together constitute these concepts. According to these accounts, the resulting embodied concepts are *iconically representational,* rather than symbolically representational, in that they, in some sense, resemble what they represent. This is because they do not merely encode information that has been abstracted and transduced from sensorimotor states and processes; rather, they are partially constituted by sensorimotor states and processes that are involved in conceptual processing in their original, non-transduced form (Barsalou 2009; Hostetter & Alibali 2008). Thus, these embodied concepts are also *modal* (tied to a particular modality or set of modalities) and *context-dependent* by virtue of involving modality-specific simulations (Solomon & Barsalou 2001).

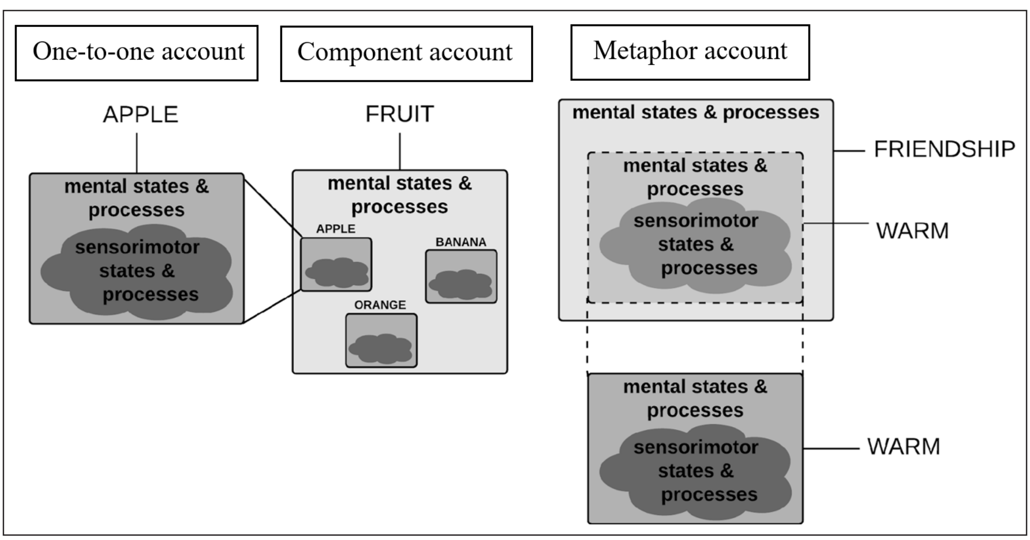

Figure 1. Diagrams of Embodied Cognition conceptual processing accounts.

In summary, Classical Computationalist and mainstream Embodied Cognition (hereafter, simply 'Embodied Cognition') theorists disagree about the *processes* involved in conceptual processing as well as the *composition* of concepts. According to Classical Computationalists, only mental states and processes (suitably restricted to higher-level neural states and processes) can be directly involved in performing cognitive functions; sensorimotor processes are limited to playing (at most) an indirect role. In contrast, according to Embodied Cognition theorists, sensorimotor states and processes (in addition to mental states and processes) are sometimes directly involved in performing cognitive functions such as learning and reasoning, and specifically conceptual processing. I will now draw on this understanding of embodied metaphors to address computational metaphors and their effects on our understanding of cognition and theories of cognition like Embodied Cognition.

3. Computational Metaphors

In the previous section, I contrasted approaches to conceptual processing in mainstream Embodied Cognition theories with those in Classical Computationalist theories—appealing to the former to explain the ways in which conceptual metaphors often shape our understanding of abstract topics. In this section, I will build on this account to address computational metaphors and how they shape our understanding of cognition. To do so, I will first argue that many computationalist statements are not literal statements but rather 1) *metaphors,* specifically 2) *conceptual* metaphors (as opposed to merely linguistic metaphors), and 3) *embodied* metaphors. I consider two sorts of statements—those according to which the *mind* is a computer as well as those according to which the *brain* is a computer (which the mind supervenes upon or is otherwise grounded in)—ultimately focusing on the latter. I address both not only for the sake of comprehensiveness but also because the lack of rigorous distinction between the two (in some literature) indicates something about the role of metaphors in these claims, and the ways they are typically communicated and defended. After sketching the ways in which one might interpret these claims, I demonstrate the difficulty of maintaining an interpretation that is explanatorily powerful and non-metaphorical (i.e. literal). I will then detail ways in which these computational metaphors may specifically bias us in favor of computational views of cognition and against embodied ones. Finally, I will claim that this biasing contributes to the resistance that Embodied Cognition faces and draw out the implications of this for how we ought to evaluate theories of cognition, in particular, Embodied Cognition and its explanatory power.

Early forms of Computationalism emerged around the 1960s, constituting a break with Behaviorism, and Classical Computationalism was the dominant theory of cognition until it was challenged by Connectionism in the 1980s, and more recently by Embodied Cognition.[18] Although it still has defenders, contemporary work in cognitive science has largely moved away from Classical Computationalism (see Pylyshyn 1993; Sprevak & Colombo 2019). However, Computationalism more broadly still serves as the foundation for much of contemporary work in cognitive science. For example, Gauthier et al. (2019, 1) attest that "representation and computation are the best tools we have for explaining intelligent behavior." Similarly, Schultz and Gava claim that

> Brains are information processing systems whose operational principles ultimately cannot be understood without resource to information theory. We suggest that understanding how external signals are represented in the brain is a necessary step towards employing further engineering tools (such as control theory) to understand the information processing performed by brain circuits during behaviour. (2019: 1)[19]

Furthermore, even more widespread than the explicit invocation of computational frameworks is the use of computational metaphors, which are by far the dominant metaphors for cognition.[20] As psychologist Gary Marcus (2015) explains, "for most neuroscientists, this [computer] is just a bad metaphor. but it's still the most useful analogy that we have…the sooner we can figure out what kind of computer the brain is, the better." And Piccinini & Bahar echo this thought—specifically highlighting the centrality of computational metaphors in philosophy and psychology—explaining that,

> While few neuroscientists take typical neural processes to be digital computations, many psychologists and philosophers are still building their theories of cognition using constructs that rely either implicitly or explicitly on digital computation, and some of them still defend digital computationalism (e.g., Fodor, 2008; Gallistel & King, 2011; Schneider, 2011). (Piccinini & Bahar 2013: 476)

18. However, according to some, some contemporary forms of Embodied Cognition can be traced back to initial forms in the work of Dewey, James, Merleau-Ponty, and Leibniz (Crippen & Schulkin 2020; Jorati 2019).

19. Also see similar statements throughout recent work by, e.g., Nicholas Shea (2018) and Paul Thagard (2019).

20. This is the case in both academic and non-academic discussions and representations of cognition. In addition to its ubiquity in academic work, the vast majority of mainstream depictions of the mind and cognition in television, film, video games, etc. are heavily influenced by this metaphor—and many rely on a literal interpretation of it.

Computational metaphors are roughly structured around the idea that the brain is 'hardware' and the mind is 'software', and include, in addition to these central metaphors, a larger family of metaphors in which other concepts from the same target domain as BRAIN and MIND (i.e. neural and mental states and processes, respectively), have been mapped onto other concepts from the same source domain as COMPUTER. For example, statements like the following are common: "cognition is computation"; cognitive information is "encoded" and 'indexed' in memory; cognition occurs through "online" and "offline" processing (Boyd 1993). We also often speak of brain "circuits," and "wiring" and of memory as the storage and retrieval of "files," which have been "encoded" and "indexed." And more casually, we say that we are running out of "bandwidth," have a low "battery" and thus need to "unplug," or that we have "short circuited" or experienced a "glitch" in our thinking. The larger metaphor undergirding such statements is that the brain (or mind) is some kind of computer and/or that cognition is computation.

Sometimes these metaphors are consciously acknowledged and invoked; however, most often, these metaphors and the frameworks they provide for thinking about cognition remains unnoticed and unacknowledged because they have become a part of the basic vocabulary that we use to speak about cognition, they strike many people, not *as metaphors* but as simply providing the most natural terms and concepts to use when speaking and thinking about cognition. This is the case even in work that does not explicitly defend or address computational views of cognition—interestingly, this is the case even in work articulating and arguing for an Embodied Cognition theory of cognition. As just one example, take Lawrence Barsalou's first chapter in Coello & Fischer's *Foundations of Embodied Cognition* (2016), in which he refers to "*online* interaction with the environment …" and the role of concepts in "*offline processing*" (12); speaks of "streams of perceptual *input* from individual *networks*" (16) and "local *outputs* of the *situation-processing architecture*" (18) and the "*encoding*" of memory (23, 27) (emphases mine). It is of course, natural to use such terms when speaking of cognition—even when speaking of Embodied Cognition; however, this just serves to underscore their ubiquity and foundational nature in how we think, write, and communicate about cognition.

3.1 Computational Metaphors as Metaphors

At this point, it is important to address the fact that many do not *think* that statements like "the BRAIN is a COMPUTER," "the MIND is a COMPUTER," "COGNITION is computation"[21], and others mentioned above, are metaphorical, instead, like Pylyshyn, they think that

> the notion of computation … is not a metaphor but part of a *literal* description of cognitive activity … it seems to me that computation, and *all* that it entails regarding rule-governed transformations on intentionally interpreted symbolic expressions, applies just as literally to mental activity as it does to the activity of digital computers. Such a term is *in no sense* a literal description of the operation of electronic computers that has been metaphorically transported to the primary subject of mind. (1993: 435, emphasis mine)

And Tim van Gelder further attests that,

> contemporary orthodoxy maintains that [cognition] *is* computation: the mind *is* a special kind of computer, and cognitive processes *are* rule-governed manipulation of internal symbolic representations. The broad idea has dominated the philosophy and the rhetoric of cognitive science… (1995: 345, emphasis mine)

However, while it is correct to say that a description of cognitive activity as "rule-governed manipulation of internal symbolic representations" is a literal description, this does not exhaust the content of statements like "cognition is computation" (or "the brain is a computer"). In other words, statements like these typically do not function merely as shorthand for the former kinds of descriptions. Such computational statements are indeed often apt and explanatorily powerful; however, this does not negate the fact that the vast majority are *metaphors.* Roughly, this means that they function as 'automatic, ubiquitous conceptual devices' that enable us to understand the brain, mind, and cognition in terms of computers and computational processes—our understanding of the former has been "mapped onto" or "scaffolded upon" the latter. One thing complicating the use of these metaphors and their recognition as such is the fact that the concept of computer is rarely addressed or unpacked when invoking these metaphors. As Piccinini explains, "philosophers interested in computationalism have devoted most of their attention to explaining mental phenomena, leaving computation *per se* largely unanalyzed" (2010: 282). There is thus a fair bit of unacknowledged confusion between, and conflation of, distinct notions of computer in much of the relevant literature.

21. Throughout the rest of this paper, I use "cognition is computation" and "the brain is a computer" as metaphors representative of the larger computational "metaphor family."

Any relevant notion of COMPUTER must be one focused on function rather than physical properties. In other words, whether the brain (or mind) is literally a computer is a matter of how it functions, not what it is "made of" (or grounded in), so to speak. The weakest version of Computationalism understands a COMPUTER as a physical apparatus that can "in theory compute any computable function"—where a "computable function" is one for which an algorithm (a finite, specific set of instructions) could specify the calculations or operations used to generate an output from the corresponding input (Richards & Lillicrap 2022). Relatedly, COMPUTATION is information processing involving the manipulation of information-bearing structures or representations to produce outputs from inputs (Piccinini 2009: 516–517).[22] This account of computers emerges from, and is most prevalent in, the computer science literature (Richards & Lillicrap 2022; Ralston et al. 2003).

When statements like "the MIND is a COMPUTER" invoke this sense of 'computer' they are, strictly speaking, committing a category error in that the mind cannot be a physical apparatus, and thus saying something false. However, when statements like "the BRAIN is a COMPUTER" invoke this sense of 'computer,' they are *literally* true—a brain is a physical apparatus that can in theory (bracketing concerns of time, energy, and resources) compute any computable function. Unfortunately, they are also explanatorily weak and fail to promote further insight into the kinds of questions about cognition at issue in philosophy, psychology, and neuroscience. This is because, depending on how broadly 'information,' 'algorithm,' 'input,' and 'output' are defined, the resulting notion of computation may be

> so loose that [it] encompass[es] virtually everything. For instance, if computation is construed as the production of outputs from inputs and if any state of a system qualifies as an input or output, [and the process generating outputs from inputs can be understood as carrying out a set of instructions] then every process is a computation. (Piccinini 2009: 517)

This very general notion of COMPUTER does not enable us to account for mental states and processes as I have delimited them above—namely, as higher-level neural states and processes involved in things like abstraction, reasoning, etc. COMPUTATION, on this account, is fairly ubiquitous and might be said to occur in a thermometer representing the ambient temperature—thus it cannot be used to capture or explain much of anything meaningful about cognition, including those topics addressed by Classical Computationalist and Embodied theories of

22. Note that there is debate about whether Computationalism requires representations, I will not engage with them but see Piccinini, 2008.

cognition.[23] Rather, these notions only typically serve as starting points for the concepts of COMPUTER and COMPUTATION—and related specifications of relevant 'inputs,' 'outputs,' 'algorithms,' and 'information processing'—most often used by philosophers and cognitive scientists.

Thus, a stronger version of Computationalism is typically relied upon in these disciplines according to which the mind is 'the software' of the brain—in other words, a program or set of programs contained within and executed by the brain, as well as the states and processes resulting from their execution. In this view, the relevant notion of COMPUTER at work in the claim that "the BRAIN is a COMPUTER" is a physical apparatus that not only can "in theory compute any computable function," but is also capable of functioning as hardware for the execution of such programs. Piccinini illustrates the centrality of these concepts in his articulations of the key claims of computationalism, functionalism, and computational functionalism. He explains that, according to computational functionalism,

> the mind is a (stable state of) a component of the brain, *in the same sense* in which computer program tokens are (stable states of) components of computers … [and] minds are multiply realizable, *in the sense in which* different tokens of the same type of computer program can run on different kinds of hardware…[and that]…mental programs can also be specified and studied independently of how they are implemented in the brain, *in the same way in which* one can investigate what programs are (or should be) run by digital computers without worrying about how they are physically implemented. (2010: 267, emphases mine)

This version of Computationalism derives much of its philosophical benefit and explanatory power from this conceptual framework—ostensibly enabling it to "demystify" the mind's supervenience on the brain and the operation of particular cognitive processes (Piccinini 2010; Simon 1996; Fodor 2000).[24] However, it is important to note that such statements are clearly *metaphorical*—which is not to say that they are vague, imprecise, or somehow "mysterious," but instead to highlight that they enable and promote scaffolding of our understanding of the mind, brain, and cognition upon our understanding of computers (software, hardware, and computation).[25]

23. Searle (1990) adopts an even more vague and permissive account of what a computer is and, on its basis, also concludes that the brain is a computer; however, he also thinks that *everything* is (or can be described) as a computer, so the brain is only trivially a computer.

24. Many thanks to an anonymous reviewer for pressing this point.

25. Piccinini clearly notes this as well—often referring to such statements as analogical or metaphorical.

This issue is further compounded in stronger versions of Computationalism which engage in more detailed scaffolding of BRAIN and COGNITION on COMPUTER and COMPUTATION—informed by features of the kinds of computers that we are most familiar with—digital computers, especially those that we use regularly (e.g. laptops, phones, etc.). As Piccinini explains, "the most relevant and explanatory notion of computation is that associated with digital computers…[which is]...based on the electronic devices we use on a regular basis and how they operate" (Piccinini 2009: 223). Here, the relevant notions of COMPUTER and COMPUTATION are digital computers and computation, respectively, and often (explicitly or implicitly) draw upon the following features.

First, the *architecture* of digital computers, which includes a *central processing unit (CPU)*—a computer chip responsible for coordinating and controlling the functions of a computer: it receives input (e.g. from a keyboard), processes the input (carries out arithmetic and logical operations based on step-by-step instructions (algorithms) provided by its *control unit*), and then sends the output to other devices (e.g. a display or printer). Additionally, digital computers include a *random-access memory (RAM)* module—a small circuit board containing a set of memory chips—which stores information the computer is currently using or processing (such as the aforementioned algorithms, information needed to run a web browser) and an *external memory* or hard drive which is used for long-term storage of things like documents and software programs. The CPU, control unit, RAM, and external memory all work together to allow a computer to perform tasks and store information.

Second, *information processing* in digital computers, which involves constant communication between the CPU, control unit, RAM, and often the hard drive and occurs through the transformation or manipulation of strings of binary digits ('bits' which can be a 1 or 0) which represent input from various sources including text, images, numbers, and audio which have been *transduced* into this form (e.g. the number '5' is represented as '101' and the letter 'A' as '01000001'). The output of this processing can then be transduced back into text, images, numbers, audio, etc. (e.g. '101' becomes '5'). This information processing is largely sequential, discrete, and passive. It processes information *sequentially* in that it executes instructions and performs computations in the specific order determined by the instructions in the program being executed—as opposed to parallel processing. It processes information in a *discrete* manner in that it operates on distinct pieces of data, one at a time, that have been encoded using a set of discrete states (represented as '1' and '0')—rather than data in the form of a continuous range of values, as is done in analog computing.[26] And its processing is *passive* in that the computer does not actively generate or modify the information or data being processed—rather it simply exe-

26. Although see Maley (2011) who argues for a different way of distinguishing between digital and analog computers.

cutes the instructions to perform the computations—in contrast to active systems.

These are just some of, although perhaps the most relevant, aspects of digital computers informing stronger versions of Computationalism, and their central concepts of COMPUTER and COMPUTATION, that are ubiquitous in philosophy and the cognitive sciences. These aspects have clearly contributed to explanatorily powerful conceptual tools and frameworks for understanding the mind, brain, and cognition. For example, aspects of the aforementioned architecture and information processing of digital computers are often used to represent how different parts of the mind work together and engage in conceptual processing.[27] Processes involved in executive functioning (such as decision-making and problem-solving) are represented as operating like a CPU, working or short-term memory like RAM, and long-term memory like a hard drive or external memory. Sensorimotor input is thought to be transduced into symbolic, mental representations in order to be processed, and once processed, transduced into outputs (e.g. actions)—on the model of information processing in digital computers. Relatedly, the relationship between cognition and the external world is understood using the model of online and off-line computer processing, and as mentioned above, the relationship between the mind and brain is modeled on that between software and hardware.

Again, these stronger versions of Computationalism clearly derive much of their philosophical benefit and explanatory power from these conceptual frameworks; and again, these frameworks and associated claims must be understood as *metaphors*. If brains were *literally* computers, on this notion of COMPUTER, they would clearly need to share their essential features, some of which I have outlined above.[28] However, while they share some of them, they do not share others. To take just a few examples, they are similar to computers (architecturally) in that they both contain short-term and long-term memory (in computers, RAM and a hard drive, respectively), as well as a 'control unit' of sorts which acts as the central processing and 'decision-making' center, involved in controlling and regulating functions (i.e. the regions involved in executive functioning like the prefrontal cortex—in computers, the CPU).[29] However, they differ (with regards

27. For example, see Cooper & Shallice (2011), Rogers et al. (2004), Schank (2014), and Thagard (2005).

28. As mentioned above, 'brain features' here refers to features of both the mind and brain.

29. Of course, there are also further differences (and similarities) once one gets into the details of these comparisons. Our memories and that of computers are both limited in capacity. However, in computers, RAM and hard drives, constitute individual modules which are solely involved in memory storage; whereas our memories are stored in a more distributed way, involving multiple brain regions which themselves are involved in other functions. Additionally, RAM is 'volatile' in that its data is erased when power is lost, whereas our short-term memory is not. Similarly, the prefrontal cortex (and other regions less centrally involved in executive functioning) differs from the CPU in that it is much more dynamic and adaptable, while the CPU must rely on a set of fixed instructions.

to information processing) in that, while computers process information passively by simply executing a set of instructions that dictate how to process input, one might think that brains additionally often engage in active processing—they manipulate information, generate new connections, solve problems, and make decisions.

To take a more detailed example, take MEMORY—the processes of memory acquisition or learning, as well as storage and retrieval, are often "mapped onto" the processes of "encoding" and "indexing" in computers, respectively. Roughly, in computers, input data are encoded into bits (1s and 0s) which are then stored in the computer's memory and indexed through the use of locations called 'addresses'—and strings of bits can then be later retrieved from storage by their address. Thus, these data are encoded (stored such that it can be accessed and used) and indexed (organized in a way that makes it easy to retrieve). These concepts have clearly provided metaphorical scaffolding for understanding human memory and its operations in work on cognition—and terms like 'encoding' and 'indexing' are often used in work in cognitive science on memory.

A clear example comes in references to 'neural encoding' which is the process by which sensory information is converted into a neural signal that can be processed and interpreted by the brain and is thought to play a key role in memory acquisition. Specific neurons are activated in response to sensory stimuli, which then transmit this information through the 'complex circuitry' of neural pathways for further processing—the specific patterns of neural activity that result from this process form the 'neural code,' from which the mind can then extract relevant information and generate a response to the stimuli (Dayan & Abbott: 2005).

There are some similarities between these two processes in brains and computers that make the latter, in some senses, an apt metaphor for the former—in both instances, patterns of activity are used to store information, enabling later retrieval. There are some similarities between these two processes in brains and computers that make the latter, in some senses, an apt metaphor for the former—in both instances, patterns of activity are used to store information, enabling later retrieval. However, there are of course also dissimilarities between the relevant types of 'codes' used—computer codes are formed by the presence or absence of electrical signals in digital circuits and logic gates to encode data in binary, enabling computer coding to be exact; whereas 'neural codes' are formed by the activation (or deactivation) of specific networks of interconnected neurons to encode information into patterns of activation, resulting in approximation rather than exactitude. And whereas neural encoding relates environmental stimuli to neural responses and is approximate, and only approximately reversible, (digital) computational coding relates classes of digital strings, is exact, and (typically) exactly reversible (Piccinini & Bahar 2013). Thus, due to key dissimilarities between the latter and the former, brains are best understood as *metaphorical* computers and cognitive processes, like those involved in memory, as *metaphorically* computational. Again, this is not to say that they are (necessarily) inaccurate, misleading, or less rigorous, but rather, to note that these metaphors provide key "conceptual scaffolding" through which we understand brains and cognitive processes in some sense *in terms of* or *through* our understanding of (in this case, digital) computers and computation—highlighting points of similarity and deemphasizing points of dissimilarity.

Thus, to summarize—first, there is confusion or at best inconsistency among authors about whether the mind or the brain is thought to be a (literal) computer. Second, in regards to the latter, weaker or more general notions of COMPUTER and COMPUTATION result in "ubiquitous computation"—in which every physical system is a computer—and are thus apt to be explanatorily useless in the cognitive sciences. Further specifying this notion by fleshing out the mind-brain relationship in terms of the software-hardware relationship results in explanatory power largely rooted in this metaphorical scaffolding. And even stronger and more specific notions of COMPUTER are almost exclusively modeled on digital computers, resulting in additional metaphors providing further metaphorical scaffolding for our understanding of the brain and cognition. Thus, it is difficult to maintain a reading of the "BRAIN is a COMPUTER" that is both explanatorily powerful and thoroughly *literal.*

One might protest that when they say "the BRAIN is a COMPUTER" they have in mind a concept of COMPUTER which only includes the points of similarity, not dissimilarity between brains and computers—and that thus understood, this and related computational statements are both explanatorily powerful and literal. For example, one might claim that all they mean when they describe the brain as a computer (or invoke other computational metaphors) is that the brain *literally* has an architecture containing a central processing or control unit, short-term, and long-term memory; or that the brain *literally* transforms input into output by carrying out "rule-governed transformations on intentionally interpreted symbolic expressions." Bracketing the fact that the second claim about information processing is precisely what is at issue between Embodied Cognition and Computationalists and thus by no means an uncontroversial claim about the mind—this is an attempt to sketch a notion of COMPUTER that cuts between weaker and stronger versions addressed above. However, this objector still must make the case that this account is both explanatorily helpful and does not end up collapsing into and thus facing the issues of either the weaker or stronger notions.

Perhaps one might think that this account does not collapse into the first account because it is merely further specifying the architecture and kind of information processing involved. However, in doing so, it appears to be merely cherry-picking features of digital computers that happen to fit with our current understanding of the brain, in an ad hoc manner. In so doing, it is constructing an understanding of 'computer' on the model of our brain, resulting in 'computer' functioning as a kind of shorthand for these cherry-picked traits. Statements using this notion of 'computer' then arise from utilizing an object (i.e. a computer) initially designed to emulate certain aspects of human cognition as the basis of a metaphorical framework for characterizing the mind and brain—thus attempting to 'read back' characteristics of the modeled object into the complex entity and processes on which it was modeled (e.g. the human brain and cognition, respectively). Thus, it is unclear how this notion of 'computer' might play a non-circular explanatory or informative role—helping to structure, inform, and deepen our understanding of cognition; furthermore, this notion does not capture much of the use of computational metaphors in the relevant literature.

Much of the resistance to acknowledging that statements like 'the BRAIN is a COMPUTER" are metaphorical can be explained by appealing to the following factors. First, some mistakenly assume that if a statement is metaphorical it is necessarily inaccurate, imprecise, or misleading. However, as addressed above, this is not the case—metaphors are oftentimes complex, precise, and apt conceptual frameworks that structure our understanding of abstract domains and concepts. As Rapaport explains "the brain doesn't have to *be* a computer in order for its behavior to be describable computationally" (Rapaport 2018: 415)—in other words, acknowledging 'the BRAIN is a COMPUTER" as a metaphor does not amount to a threat to Computationalism. Second, the ubiquitous, entrenched, and foundational nature of many of these metaphors, may lead to psychological difficulties recognizing or acknowledging them as metaphors.[30] For example, some studies have demonstrated that subjects who are impacted by metaphors are often unaware of this impact and even the presence of metaphors having the impact (Thibodeau & Boroditsky 2011; Amin et al. 2018).[31] These effects are further compounded by the fact that many philosophers, psychologists, and neuroscientists have limited knowledge of the underlying concepts and principles of computation (Richards & Lillicrap 2022). This can result in a lack of awareness and/or acknowledgement of when a researcher is drawing on one as opposed to another of these notions, especially in work that is not focused on addressing these notions.

30. This point may be even clearer upon thinking back to previous mechanical metaphors which compared the mind to the latest technological innovations: Descartes spoke of the brain as a sort of hydraulic pump, Freud likened it to a steam engine (Marcus 2015). "Before computers came along, there were many other physical metaphors for the brain: The brain was considered to be like a telephone system or like a plumbing system…Because these have fallen out of favor and we have more distance from them, we can immediately see them as metaphors—metaphors that are apt for understanding some features of the mind, but ill-fitting for others." (Rapaport 2018: 413).

31. I will address some of these studies, especially Thibodeau and Boroditsky's (2011), below.

In summary, understanding the statement "the BRAIN is a COMPUTER" literally restricts one to making only very basic claims about the brain and its capacities. Thus, it is reasonable to assume that often when this statement (or many of the related statements in the same metaphor family) is made in academic literature—specifically in philosophy, psychology, or neuroscience—it is being used to make more substantive claims about the brain and/or cognition. However, grounding these more substantive claims relies on invoking more explanatorily powerful notions of COMPUTER—that are grounded in specific traits of program-based and/or digital computers—to metaphorically scaffold such claims. Now that I have made the case that many statements invoking a Computationalist framework are *metaphorical* rather than literal—I will turn to argue that they are specifically *conceptual* metaphors (as opposed to merely linguistic metaphors), and *embodied* metaphors (rather than disembodied ones). Their status as conceptual, embodied (and conventional) metaphors strongly supports claims that Computational metaphors powerfully shape cognition.

3.2 *Computational Metaphors as Conceptual*

Recall that conceptual metaphors are "automatic, ubiquitous conceptual device[s]" that structure and inform our thinking. Specifically, they enable us to think about and understand less familiar (and in some sense, more abstract) things in terms of more familiar (and in some sense, more concrete) things (Finsen et al. 2019). While a merely linguistic metaphor only enables us to *communicate about* more abstract concepts in terms of more familiar and concrete concepts; conceptual metaphors also enable us to *think about* more abstract concepts in terms of more familiar and concrete concepts. Thus, much of what I addressed in the section above in support of the claim that statements like "the brain is a COMPUTER" invoke a *metaphor,* also can provide support for the claim that such statements invoke a *conceptual* metaphor, specifically.

Clearly, such metaphors are integral to how we *speak* about cognition and ubiquitous in academic work (as well as in casual conversation) addressing the brain and cognition, even in work that does not explicitly invoke or engage with Computationalism. As Richard Boyd attests, these computational metaphors have played a central role in work on cognition. He explains that exploring

> similarities, between men and computational devices has been the *most important single factor* influencing postbehaviorist cognitive psychology. Even among cognitive psychologists who despair of actual machine simulation of human cognition, computer metaphors have an *indispensable role* in the formulation and articulation of theoretical positions. These

> metaphors have provided much of the *basic theoretical vocabulary of contemporary psychology*. (1993: 487, emphases mine)

The centrality and foundational role of computational metaphors then give us reason to believe that these metaphors reflect an underlying conceptual framework in which our *understanding* of the brain and cognition is shaped by and associated with computers—specifically our understanding of and experiences with them. Much of current mainstream work in cognitive science is explicit about the central role of such conceptual frameworks—for example, Gauthier et al. (2019: 1) proclaim that "representation and computation are the best tools we have for explaining intelligent behavior."[32]

According to some, computational metaphors are so central to Computationalist accounts of cognition that they are what is known as "theory-constitutive metaphors." For example, Finsen et al., echoing Boyd, claim that,

> it is not the case that scientists and philosophers employ the [BRAIN is a COMPUTER] metaphor to pedagogically present an otherwise incomprehensible hypothesis about cognition to the general public. Rather, the computer metaphor of the brain *is the very hypothesis*. This type of scientific metaphor is known as a theory-constitutive metaphor (Boyd 1993), i.e., a metaphor that forms the conceptual basis of a scientific paradigm and cannot be translated into more literal language. (Finsen et al. 2019: 321)

In brief, statements about and descriptions of cognition often invoke computational metaphors and because these metaphors are so foundational and ubiquitous, it stands to reason that they are conceptual metaphors—meaning that they speak to the ways in which our understanding of the brain and cognition has been shaped by Computationalist conceptual frameworks. Naturally, one would seek empirical support for such claims, demonstrating the conceptual effects of such metaphors; however, there has thus far been a dearth of such work—either investigating the influence of computational metaphors or more generally metaphors for the brain.[33] However, we can draw on more established empirical research investigating the influence of conceptual metaphors which are somewhat similar to computational metaphors (in that they deal with similarly abstract and complex target concepts) to draw further support for claims that computational metaphors are similarly conceptual. One such study comes from Amin et al. who explain that,

32. Also, see recent work by Nicholas Shea (2018) and Paul Thagard (2019).
33. Although see Finley (under review1, under review2) in which I address this.

> implicit in the language of science are systematic metaphorical mappings between abstract scientific concepts (such as heat, energy, and entropy) and concrete image-schemas (such as material object/substance, possession, containment, object movement, and forced object movement). These implicit mappings (referred to as conceptual metaphors) are reflected in the language of science, as in "the molecule *has* kinetic energy" … "heat was *lost* to the surroundings." (2018: 2, emphases mine)

These metaphors are integral to communication on these topics and many studies indicate that they are also integral to understanding and thinking about them—in other words, they are conceptual metaphors. For example, Brookes & Etkina have conducted multiple such studies (2007; 2009; 2015). In their most recent, they address the role of metaphors for HEAT in students' reasoning about heat in thermodynamic processes. On the basis of their own and other studies, they conclude that undergraduate physics students' reasoning tendencies in solving problems about thermodynamic processes reflect the metaphorical ways of understanding heat encoded in the language that they use. Specifically, they found correlations between the use of substance-based metaphors for HEAT (heat is a "substance that moves from one location to another", thermodynamic systems are envisioned as "containers" of heat, and temperature is seen as measuring the amount of heat "in" an object) and a tendency to reason about heat "as a state function" even in problem-solving contexts in which it is inappropriate. Jeppsson et al. (2013) reported similar findings from their studies conducted with physics Ph.D. students on metaphors for HEAT and ENTROPY.

Notably, in a later study—also on the use of conceptual metaphors in the reasoning of physics Ph.D. students—Jeppsson et al. (2013) conclude that through metaphors, "concrete construals of abstract concepts such as entropy, energy, and heat in terms of possessions, movement of possession and containment in the context of advanced scientific problem-solving can be *more prevalent at higher levels of expertise*, and not necessarily a sign of naïve reasoning" (799). They go on to suggest that familiarity with and deep integration of conceptual metaphors may play a key role in the development of scientific expertise. In a similar vein, Alibali and Nathan (2012), Goldin-Meadow et al. (2009), Lakoff & Nunez (2000), Nemirovsky et al. (2012), and many others have investigated the impact of metaphors in mathematics; and others like Bleakley (2017), Nie et al. (2016), and Tate (2020) in medicine; Luhrmann (2011) in anthropology; and Niebert & Gropengiesser (2015) in psychology.[34]

The metaphors in the studies above are clearly *conceptual* metaphors in that their use or activation shapes reasoning about the target domain to be more in

34. I address some of these studies in more detail below.

line with the similarities between the source and target concepts highlighted by the metaphors. Furthermore, this research demonstrates that such metaphors can impact the thinking of lay people and students, as well as experts and practitioners—thus indicating that at least some conceptual metaphors truly function as *conceptual* metaphors for the latter group, who know the most about the target domain.[35] Because conceptual metaphors help us think about and understand more abstract and less familiar concepts in terms of more concrete and familiar concepts, it makes sense that they are integral to how we understand many scientific concepts (e.g. HEAT, ENERGY), mathematical concepts (e.g. ADDITION), and I argue, philosophical concepts like BRAIN and COGNITION.

3.3 *Computational Metaphors as Embodied*

Thus far I have presented reasons to think that computational metaphors are specifically *conceptual* metaphors for cognition and now I turn to address why we ought to think that these metaphors are also *embodied*.[36] Recall that conceptual metaphors result from cross-domain mappings which enable us to understand less familiar, more abstract concepts through association with more familiar, more concrete concepts. Often these more concrete concepts are closely tied to perceptual domains and thus likely grounded in one's sensorimotor experiences—because of this, some claim that most if not all conceptual metaphors are embodied. I think there are additional reasons specific to computational metaphors to believe that these metaphors are embodied. For most people (specifically those without an advanced understanding of computers) many of their relevant concepts in the source domain (e.g. COMPUTER, COMPUTATIONAL, ENCODING) are in large part constituted by their (embodied) experiences of computers (e.g., typing on a keyboard, moving a mouse, clicking buttons on a screen, viewing representations of computers and computation in popular media, etc.)—and perhaps even constituted by more concrete concepts grounded in these experiences. Recall that when different computer concepts are properly disambigu-

35. Unsurprisingly, some metaphors have been found to have a stronger impact on those who have only a rudimentary understanding of the target domain and a weaker impact on those with an advanced understanding of the target domain and/or deeply held beliefs about the target domain. For example, Thibodeau and Boroditsky (2013) found that those with more deeply held beliefs about crime were less impacted by the crime metaphors they employed ("CRIME is a VIRUS," "CRIME is a BEAST"). However, I believe the studies cited above involving Ph.D. students and professionals in scientific disciplines—presumably with their own deeply held beliefs about the subject material—are a closer analogue to those impacted by computational metaphors who I address here.

36. Recently, in work on metaphor, increased attention is being paid to debates addressing the embodied vs. discursive nature of metaphors (Hampe 2017).

ated, it becomes clear that the COMPUTER concepts (and related computational concepts) used in relevant literature are grounded in our everyday, embodied experiences of digital computers. And when one tries to understand computers or specific computational functions by abstracting or generalizing away from the instantiation of such functions in literal computers, these descriptions lose much of their explanatory power (Boyd 1993; Finsen et al. 2019).

Interestingly, among embodied metaphors, computational metaphors may even be *especially* influential on our thinking because the sensorimotor experiences of computational devices that they rely on are ubiquitous, everyday experiences (Adbo & Taber 2009; Niebert et al. 2012).[37] Furthermore, these sensorimotor interactions with computers often occur while engaging in higher-level cognitive processing (e.g., typing out a paper, recording notes on course material, researching, etc.)—which may thus further strengthen the association between concepts in the source and target domains. Again, naturally one would hope to find empirical support for such claims—demonstrating the role of embodied experiences with computers in mediating the cognitive effects of these computational metaphors—but again, there is a dearth of such work.

However, we can again draw on empirical research investigating the influence of embodied, conceptual metaphors in the sciences and mathematics to further support the plausibility of these claims. In one study, Robert Goldstone et al. argue for the occurrence of a kind of neural reuse in those engaging in mathematical reasoning. Their participants made use of gestures and embodied metaphors which were clearly grounded in sensorimotor activities when reasoning through the problems they were given. Summarizing their results, they explain that,

> It is widely assumed that, as it develops, mathematical reasoning shifts toward abstraction. But our initial observations of mathematicians "in the wild" suggest that their reasoning depends on *spatial perceptual grouping strategies* and *actions over space*. Sophisticated reasoners are at least as likely to employ concrete actions as novices—they just apply them more efficiently and felicitously. (2017: 439, emphases mine)

As they note, while mathematical reasoning is often thought of as a paradigm instance of abstract thinking that wouldn't rely on sensorimotor states and processes, it appears that it does. Furthermore, they note that this reliance on sensorimotor strategies simply changes rather than dissipates in 'sophisticated' or

37. According to a 2019 study (Perrin & Kumar), about a third of those in the US reported being online "almost constantly," and these figures have almost certainly increased in recent years due to the COVID pandemic. Additionally, in 2022, 25% of workers reported working fully remotely, and 60% partially remotely (necessitating even more computer use) (Dua et al., 2022).

expert reasoners. Similarly, Lakoff and Núñez address the embodiment of mathematical concepts extensively in their book *Where Mathematics Comes From: How the Embodied Mind brings Mathematics into Being* (2000). One example they address at length is the embodiment of the metaphor in which the target concept of EQUATION is mapped onto the source concept of BALANCE—which again is grounded in past physical experiences of balance. In a similar vein, in the sciences, Scherr *et al.* (2013) and Close and Scherr (2018), have conducted multiple studies surrounding their embodied learning activities which they call 'Energy Theater' that reveal compelling connections between student gestures and movements around the room in different configurations and their learning and reasoning about energy through metaphorical frameworks. Based on students' articulation of their reasoning about energy after such activities, the researchers hypothesize that this reasoning was impacted by the relevant metaphor (ENERGY is a SUBSTANCE) which was developed through their sensorimotor activities.[38]

Additionally, while there are many studies addressing the role of conceptual metaphors in the reasoning of experts, as opposed to learners—there are few that address the explicitly *embodied* elements of it. However, there's no reason to suspect that the embodied element of conceptual metaphors would play less of a role in impacting the reasoning of experts, and recall that some hold that *all* conceptual metaphors are necessarily embodied. Furthermore, it is important to keep in mind that those with expertise in any subject were at one point merely learners and thus the metaphors they used to learn about the relevant subject are essentially still "baked into" their now expert understanding—as is evidenced by the continued appearance of these metaphors in academic writing on these topics. For example, researchers have found persistent misconceptions about how heat and energy operate that can be traced back to the influence of these metaphors even among experts researching these topics (Brookes & Etkina 2015; Chi et al. 1994). And again, there are some empirical findings that suggest that, at least in some disciplines, they may play *even more* of a role in the reasoning of experts than in that of non-experts. For example, in Jeppsson et al.'s (2013) study cited above, they note that when comparing the role of conceptual metaphors in the reasoning of physics undergraduate and Ph.D. students (at the end of graduate school) the use of conceptual metaphors by the latter to a much greater extent than the former "transformed what might have been expected to be highly formal reasoning to a process of reasoning that contained many elaborate concrete, imagistic scenarios …" (798). Roughly, the reasoning articulated by the Ph.D. students relied even more on embodied, conceptual metaphors than that of the undergraduate students.

38. Also see Alibali & Nathan (2012), Goldin-Meadow (2005), Herrera & Riggs (2013), Niebert et al. (2012), and Niebert & Gropengießer (2015) for similar research.

These are just a few of the many examples that, when taken together, make a compelling case for the role of embodiment in such metaphors. Crucially, in many of these studies, researchers demonstrated not only that sensorimotor processes played a role in participants' learning and understanding of the relevant concept(s) but that they played a *direct* role that was *distinct* from the other kinds of instruction they received. For example, Goldin-Meadow et al. (2009) demonstrated that gestures taught to some participants contributed to their learning of ADDITION by providing information distinct from the verbal instruction they received. These studies demonstrate the role of sensorimotor activities in mediating the effects of metaphors on cognition, specifically on learning—thus making a compelling case that these metaphors are embodied. Furthermore, it is notable that these studies report a measurable impact in real-time, short-term embodied activities—repeated embodied experience may have even stronger effects. In summary, this research on embodied, conceptual metaphors in mathematics and the sciences gives us reason to think that computational metaphors may be similarly embodied, conceptual, and have measurable effects on cognition. Now I will turn to detailing the potential effects and implications of these effects on our understanding of and debates about theories of cognition.

4. Effects of Computational Metaphors

Thus far I have detailed an account of computational metaphors and have presented reasons to think that they (at least many in the metaphor family) are both conceptual and embodied—thus in what follows, I will merely refer to 'metaphors' when speaking of conceptual and embodied metaphors and when I refer to 'computational metaphors' I am speaking of those that are conceptual and embodied. Now, I will address ways in which these computational metaphors may impact our understanding of cognition through effecting: (1) the content of the relevant target concepts, (2) the cognitive availability of other metaphors, and (3) the plausibility of related non-metaphorical statements; as well as (4) the fact that many of these effects often go unnoticed and are often misattributed. In each of these sections, after presenting the relevant research on the effects of metaphors, I will articulate how these effects may be at work in the influence of specifically *computational* metaphors in the debates and conversations surrounding *cognition*. Then, I will sketch the potential implications of this for the debate surrounding Embodied Cognition. Roughly, I will claim that computational metaphors bias our thinking about cognition in favor of computational and against embodied theories of cognition.

4.1 Effect on Target Concepts

First, metaphors affect the content of their target concepts because of associations drawn between the target and source concepts. For example, take Thibodeau and Boroditsky's study (2011; 2013) in which they gave two groups of subjects information about crime in a fictional town: both groups were given the same crime statistics, accompanied by one of two vignettes that employed either the metaphor "CRIME is a BEAST" (e.g. metaphorical statements about needing to "hunt down" and "capture" criminals) or the metaphor "CRIME is a VIRUS" (e.g. metaphorical statements about needing to "diagnose" and "treat" the crime that had "infected" the city). When presented with a list of potential approaches to addressing the city's crime, subjects were more likely to support enforcement-focused approaches (such as catching and jailing criminals and enacting harsher enforcement laws) when they were given the "crime is a beast" vignette and were more likely to support reform-focused approaches (such as eradicating poverty and improving education) when given the "crime is a virus" vignette. Researchers hypothesize that this occurred because reading the metaphors affected participants' understanding of crime to be more like a virus or to be more like a beast: the former a view in which the systematic nature of crime was emphasized and the latter one in which the importance of individual aggressors was emphasized.

These effects are stronger the more conventional (familiar and widespread) a metaphor is. According to the *Career of Metaphor* theory when someone is exposed to a novel or unfamiliar metaphor, it is processed as a comparison, in which pre-existing similarities between the target and source concepts are highlighted. However, when presented with a conventional metaphor, it is processed as a categorization, in which the target concept is in some way thought of as belonging to the category defined by the source concept, thus "inheriting" some properties of the source concept (Bowdle & Gentner 2005; Gentner & Bowdle 2001; Glucksberg et al. 1997). Sometimes, this "inheritance" can occur to such an extent that the conventional metaphor is often thought to be literally true. Ervas et al. (2018), after analyzing theirs and others' research on the topic, claim that in the studies they examined, in virtue of the metaphors with them, "the majority of sentences with conventional metaphors [were] perceived as [literally] true, even though they [were] literally false."

Research on the target concepts of HEAT and ENERGY, addressed above, provides additional evidence of these kinds of effects. Conventional metaphors, like those mentioned above, "map" HEAT and ENERGY onto material substances. As a result, in those who have learned these concepts through such metaphors, HEAT and ENERGY are metaphorically categorized as kinds of material substances, thus "inheriting" some properties of material substances, and in some cases being misunderstood to be literally material substances. These effects manifest in how these concepts are spoken about (e.g. as mentioned in the quote above, using phrases like: "the molecule *has* kinetic energy…[and] heat was *lost* to the surroundings" (Amin et al., 2018, emphases mine), and have implications for how they are thought about. (As addressed above, these metaphors seemingly contributed to students assuming this material understanding of heat and/or energy when attempting to solve problems involving these concepts.) Thus, the target concepts involved in these metaphors (HEAT and ENERGY) seem clearly affected by their metaphor associations with material source concepts, and these effects are perhaps even stronger because they are conventional metaphors.

Now, turning to (conventional) computational metaphors, the target concepts would presumably "inherit" some properties of their corresponding source concepts: BRAIN inheriting some properties of COMPUTER, our concept of MEMORY inheriting some properties of RAM or external hard drives, and the process of information storage within them. Thus, the brain, cognition, and cognitive activities would unsurprisingly be seen as more computational. It is important to highlight that because computational metaphors are conventional it is not the case that they merely make salient pre-existing similarities between brains and computers, but rather that the brain is metaphorically categorized as a *kind of computer*. This effect is likely especially pronounced in the case of computational metaphors because not only are they conventional metaphors for the brain, they are by far the most common—in contrast to many of the concepts in the sciences addressed above, like ENERGY, for which there are multiple common metaphors. This means that concepts like BRAIN and MEMORY are most often "inheriting" computational properties and not properties of other, potentially more embodied, metaphors for the brain. One upshot of this is then that the dominance of computational metaphors for the brain may lead the central concepts themselves (e.g. BRAIN, MEMORY) to be seemingly more aligned with computational as opposed to embodied theories of cognition. Circling back to §2.1, the phenomenon addressed in this section perhaps helps make further sense of the temptation to maintain that statements like "the BRAIN is a COMPUTER" are literally true. While there may be other reasons behind attempting to maintain the literal status of such statements, some of which I addressed above, it is notable that many who employ these computational metaphors do take them to be literally true, and that this is a well-known effect of conventional metaphors.

4.2 Effect on Other Metaphors

In addition to affecting the content of their target concepts, metaphors also affect the cognitive availability of other metaphors—as Thibodeau and Durgin note, metaphors "encourage the speaker to use, and prepare the listener to understand, other metaphors that rely on the same mapping" (2008: 532). Roughly, when a certain metaphor is "activated" this affects the "cognitive availability" of other metaphors—in other words how easily these metaphors can be called to mind and thus how intuitive and automatic it is to use them. When a metaphor is activated, it increases the cognitive availability of other, related metaphors (those that rely on mappings between the same domains) and correspondingly, decreases the relative cognitive availability of metaphors that rely on different mappings. The existence of metaphor families—sets of metaphors in which concepts from the same target domain are mapped onto other concepts from the same source domain—provides compelling evidence of this phenomenon (Lakoff & Johnson 2008; Thibodeau & Durgin 2008). Metaphor families form because conventional metaphors (those that are familiar) enable us to more easily understand and use novel (unfamiliar) metaphors that rely on similar mappings.

To see some of the effects of this, let's return to Thibodeau and Boroditsky's study (2011; 2013). After being presented with the "crime is a virus/beast" vignettes, subjects were asked open-ended questions including "how they would recommend solving [the fictional city] Addison's crime problem." (Thibodeau & Boroditsky 2011; 2013). Subjects' responses were more likely to contain metaphors that belonged to the same metaphor family as the metaphor they were given in the vignette: those given the 'crime is a beast' vignette were more likely to mention things like 'hunting down' and 'capturing' in their responses, while those given the 'crime is a virus' vignette were more likely to mention things like 'diagnosing', 'treating', and 'inoculating' in their responses. Because of the metaphors that participants were initially given, they found it more natural to use metaphors that, while not explicitly mentioned in the vignette, were in the same metaphor family as those originally given to them (e.g. thinking of CRIME as a VIRUS made more cognitively available by metaphors like "the CITY is a BODY" which thus prompted body-related metaphors to be preferred in some of the recommended solutions like "inoculating the city to further crime through education").

As I've addressed above, the family of computational metaphors is ubiquitous in how we think, write, and talk about cognition. According to the aforementioned effects of metaphors, when metaphors in this family are activated, related metaphors become relatively more cognitively available while unrelated metaphors become relatively less cognitively available. This then means that using computational metaphors to address cognition may make other computational metaphors more readily spring to mind, seem more intuitive, apt, and thus more likely to be used. By the same token, it may make other metaphors for cognition, say those in-line with an embodied approach (e.g. "the BRAIN/MIND is a MUSCLE" or "the BRAIN/MIND is a GARDEN") less cognitively available, less intuitive, seemingly more ill-fitting or less apt, and thus less likely to be used. This effect is especially notable in the case of computational metaphors because they are the dominant metaphors for cognition. This means that the domination of computational metaphors may lead to an inherent friendliness towards further metaphors that fit with a computational framework and inherent resistance towards those that do not.

4.3 Effect on Non-Metaphorical Statements

Metaphors also tend to increase the cognitive accessibility and plausibility of non-metaphorical claims that fit with the metaphor and decrease that of those that don't. For example, take Niebert and Gropengiesser's (2015) study in which they looked at subjects who learned about myelin sheaths (layers formed around nerve cells that enable electrical impulses to travel along them) using the metaphor of a container (i.e., "MYELIN is a CONTAINER for the nerve cells"). They found that it was easier for these subjects to make sense of (non-metaphorical) claims about functions that fit with the metaphor (e.g., "myelin sheaths *protect* the nerve cells") and more difficult for them to make sense of claims about functions that did not (e.g., "myelin sheaths *affect the signal speed* of electrical impulses traveling along nerve cells"). As one student explained, "I *cannot imagine* how myelin affects the traveling time of signals, it prevents ions from leaving the neuron. The distance a signal has to travel in the neuron is the same with or without myelin" (2015: 12, emphasis mine).

The authors propose that because subjects learned about myelin through the "MYELIN is a CONTAINER" metaphor, this made it easier for them to understand and find plausible functions of myelin that made sense as being carried out by a container than it was for them to understand those that did not. For some, like the subject quoted above, this occurred to the extent that the functions that did not fit with the container metaphor were *unimaginable*. And these metaphor effects seem to be particularly strong when the metaphor in question plays a central role in one's learning about the concept. According to some, this also has implications for argument evaluation.[39]

As discussed above, computational metaphors are ubiquitous and central to how we learn about and understand concepts like the BRAIN and COGNITION. This may in turn contribute to people finding claims and theories about cogni-

39. Additionally, these effects have been found to not only impact the evaluation of statements but also of entire arguments—for example, Glucksberg (2003) found that subjects are more likely to evaluate arguments as valid and sound when one of the premises contains a conventional metaphor.

tion that fit with computational metaphors—most obviously, Computational theories of cognition—more understandable and perhaps more plausible than those that do not, e.g. Embodied Cognition theories. In some cases, this may even contribute to difficulty in fully conceptualizing these claims or theories that do not fit. We may see some of this "imaginative resistance" towards non-computational theories often reflected in statements about Computationalism. For example, Van Gelder (1995: 346) remarks that "…one of the most influential arguments in favor of the computational view is the claim that there is simply no alternative. This is sometimes known as the 'what else could it be?' argument." Here we see Van Gelder noting that a primary motivation for many in adopting a Computationalist theory of cognition is that this theory is, in some sense, the *only imaginable* theory of cognition. Of course, these effects of metaphor are not the only potential cause of such imaginative resistance; however, as I will address below, it is notable that in debates about theories of cognition, there are often expressions of strong *imaginative* resistance against embodied theories of cognition, and that this is a well-known effect of metaphors.

Bringing together the effects addressed above yields the following picture of computational metaphors and their purported impact on our understanding of cognition. Computational metaphors constitute a family of conventional, conceptual metaphors in which the brain and cognitive processes are mapped onto, and thus closely associated with and understood in terms of, computers and computational processes. These metaphors are ubiquitous and when activated may result in the following. Within the relevant *target concepts* (e.g., BRAIN, MEMORY, etc.), pre-existing attributes shared with computers and computational processing may be more cognitively salient, and additional computational attributes may also be "inherited"—resulting in the target concepts being understood as more computational. Additionally, other *metaphors* (e.g. MEMORIES are ENCODED) and *non-metaphorical* statements (e.g. perceptions are transduced into amodal, symbolic representations) about cognition that align with these concepts may become more cognitively available and thus be seen as more plausible and intuitive—and those that do not align may become less so.

4.4 Unnoticed & Misattributed Effects

A final notable finding about the influence of computational metaphors is that people who experience these effects are often unaware of them as well as the fact that metaphors caused them and thus tend to misattribute these effects (Correia 2011; Ervas et al. 2018; Robins & Mayer 2000; Thibodeau & Boroditsky

2013).[40] Relatedly, Glucksburg (2003) argues that metaphor comprehension is both automatic and unavoidable, in that people cannot ignore metaphors even when a literal interpretation makes sense in context—in such situations, they still experience measurable effects of metaphor. For example, in Thibodeau and Boroditsky's study (2011; 2013) above, they found that although the majority of participants seemed to be impacted by the "CRIME as a VIRUS/BEAST" vignettes they were presented with, most subjects were unaware of this impact. Many were even unaware of the mere presence of the metaphor in their vignettes—and some were even unable to recall which metaphor they were given when asked. Because of this, when subjects in the study above were asked what informed their decision to favor the approaches that they did, the majority of subjects did not cite the metaphors or vignettes and instead cited things like the crime statistics (which all participants in both metaphor groups were given). In other words, a participant in the "virus" group might say that they selected reform-focused approaches to address the crime because they thought it justified by the crime statistics and other details presented to them—and a participant in the "beast" group would say the same thing, except maintaining that the same statistics and details instead justified an enforcement-focused approach.

Even more striking, metaphors that are *very* conventional—in other words, those that recur frequently in language, imagery, etc.—appear to become activated and influence judgments after only a single mention of the metaphor (Thibodeau & Boroditsky 2011), or sometimes in the absence of any mention at all. For example, in the absence of activation of these metaphors, words related to goodness are more quickly recognized when presented higher in vertical space (as opposed to lower), consistent with the metaphor "GOOD IS UP" that we invoke when saying someone is "moving up in the world" or "rising to the top" (Meier & Robinson 2004). And objects are perceived to be more important when they are physically heavier, consistent with the metaphor HEAVY IS IMPORTANT we refer to when we speak of things "carrying weight" or "weighing us down" (Chandler et al. 2012). All of this highlights the ways in which metaphors can serve as "lenses" through which incoming information is filtered. The issue is not that we need or often use these "lenses" (clearly metaphors play an important conceptual role), that they impact how we "see things" (metaphors help scaffold understanding), nor that they are of a particular "color" (inevitably, metaphors will have particular content)—instead the issue is that we (often) don't even "see" that the "lenses" are there, instead attributing the effects of metaphor to the information we are taking in.

40. Relatedly, as addressed above, whether someone experiences these effects of a metaphor does not depend on whether the person *thinks* that it is a metaphor.

Turning back to computational metaphors—the upshot of this is that, if computational metaphors lead to effects like those sketched above, then those who experience these effects will likely be unaware of them and thus likely to misattribute them—or fail to attribute them altogether.[41] And again, this effect is also likely compounded by the fact that, as addressed above, computational metaphors provide much of the foundational theoretical vocabulary for discussing and thinking about the brain and cognition, thus it is even *more* difficult to recognize them as metaphors. However, if the effects of metaphors are "mandatory and automatic" then being unaware of the presence of computational metaphors or their status as metaphors does not exempt one from their cognitive effects.

Bringing this together with the research above means that even though someone may think that: 1) computational metaphors are literal statements about cognition; 2) computational metaphors just "fit" better with our understanding of the brain or are much more intuitive, plausible, or apt; 3) certain statements or arguments about cognitive capacities that "fit" with a computational framework are more plausible than those that don't—the research presented above gives us strong reason to suspect that (1)-(3) may all in some measure be caused by computational metaphors, which at the very least ought to give them reason for increased skepticism towards these beliefs. Furthermore, they may also think 4) that they are unaffected by computational metaphors—and again, the current research on this topic should give them reason to hesitate. Roughly, computational metaphors—along multiple dimensions—likely bias us towards a more Computationalist understanding of cognition and are also unlikely to register as the causes of this bias, especially, and ironically, on a Computationalist understanding of cognition.

5. Implications for Embodied Cognition

In the previous section, I presented some key effects of metaphors and sketched how computational metaphors might impact our understanding of cognition through these effects. Now, I will articulate some of the potential implications of this for the understanding and evaluation of Embodied Cognition. In short, I will argue that if computational metaphors affect our understanding of cognition in the ways described above, then they bias us in favor of Computationalist theories of cognition, and thus against Embodied Cognition theories. I will then briefly address how this feature of Embodied Cognition—the fact that it is able to offer a satisfying account of some resistance against it—speaks in favor of its explanatory power.

41. There are also many other effects of metaphors that I did not have the space to address in depth here—including their impact on attention (Bowes & Katz 2015; Thibodeau et al. 2016) and memory (Katz & Taylor 2008; Perrott et al. 2005).

As I addressed above, these effects of computational metaphors may result in the relevant *target concepts* (e.g. BRAIN, COGNITION, MEMORY) being more computation-like; increased cognitive availability of *other metaphors* that use a similar mapping (of a cognitive process or function onto a computational process or function); and an increase in the plausibility of relevant *non-metaphorical statements* that align with computational views (e.g. 'concepts are constituted by amodal, context-independent, symbolic mental representations'). Consequently, because concepts like BRAIN, COGNITION, and MEMORY are more computation-like they may be seemingly less amenable to the kinds of accounts provided by Embodied Cognition. Embodied metaphors for cognition will also be relatively less cognitively available and thus intuitive, and non-metaphorical statements expressing tenets of Embodied Cognition—specifically those that clash with a computational picture of the brain—will also seem relatively less plausible, perhaps even less comprehensible. Insofar as computational metaphors provide much of the basic theoretical vocabulary for addressing cognition, they also provide much of the basic conceptual framework for understanding cognition—which, insofar as it is aligned with a computational picture of the brain is largely at odds with an embodied one. And this may plausibly lead to increased resistance against embodied theories of cognition and perhaps the strongest resistance against those that depart furthest from Classical Computationalism—Radical Embodied Cognition, or enactive theories of cognition.

There is, however, a lack of empirical research supporting such claims about these specific metaphors, but the empirical evidence of the effects of metaphors sketched above provides some support.[42] Additionally, the following phenomena may point in this direction. Notably, the use of embodiment-friendly metaphors for cognition (e.g., the BRAIN/MIND is a GARDEN/PLANT, the BRAIN is a MUSCLE), in academic literature pales in comparison to that of computational metaphors—and when it does occur, it does so outside of work that specifically engages with the concepts of cognition and cognitive processing (in philosophy, psychology, neuroscience, etc.). For example, the "BRAIN/MIND is a GARDEN/PLANT" (i.e. ideas are "seeds," beliefs can be "deeply rooted," etc.) metaphor, when it does appear, mostly does so in work on education and learning (Ahmady et al. 2016). Similarly, the "BRAIN/MIND is a MUSCLE" metaphor (i.e. cognitive skills can be "strengthened," one can be mentally "stretched" and experience mental "cramps," etc.) is most likely to appear in work in education (Dweck 2008) as well as work in disciplines like dance and kinesiology (Rainer 1961).

Interestingly, certain statements made in opposition to Embodied Cognition also seem to signal the kind of intuitive rather than content-based resistance—analogous to the examples above in which participants were less able to,

42. See Finley (under review1, under review2) for more on this.

or unable to, fully comprehend traits of myelin that didn't comport with the container metaphor they had used to learn about it. And this more intuitive resistance is what we might expect to result from the lack of alignment between the claims of Embodied Cognition and computational metaphors for cognition. For example, Goldinger et al. (2016) claim that,

> for the vast majority of classic findings in cognitive science, embodied cognition offers *no scientifically valuable insight*. In most cases, the theory has *no logical connections* to the phenomena, other than some trivially true ideas. Beyond classic laboratory findings, embodiment theory is also *unable* to adequately address the basic experiences of cognitive life… [and continues to say of the regular everyday cognitive phenomena that] *None* can be plausibly explained, *or even meaningfully addressed*, by the principles of Embodied Cognition." (2016: 959–960 , emphases mine)

Claims like these—according to which Embodied Cognition offers *nothing* of value to our understanding of cognition—are characteristic of a certain strand of resistance to Embodied Cognition. However, of course, many of those who object to Embodied Cognition *are* nevertheless able to make sense of and recognize the value of some of its claims. In all of these instances, although we are unable to definitively prove the role of computational metaphors in motivating and shaping some of this resistance—the reasons given thus far give us strong reason to suspect that they do indeed play a role.

To be clear, I am not proposing that the influence and ubiquity of computational metaphors are the sole (or even the main) reason for resistance or objection to Embodied Cognition claims. Neither am I claiming that those who are impacted by computational metaphors in the ways sketched are unable to overcome their influence in their reasoning about theories of cognition. However, I believe that the research highlighted above, combined with the ubiquity and foundational nature of computational metaphors for cognition makes it quite plausible that it plays some role—and that this role may be one that in some cases causes and in others amplifies resistance against embodied theories of cognition. Furthermore, based on the research highlighted above, we ought to be cautious about our ability to discern how much of a role they play. Recall that many of the effects of metaphors (effects on cognitive accessibility, comprehensibility, and plausibility) are likely to be unnoticed and misattributed to other causes—this could of course lead to metaphor-motivated resistance to Embodied Cognition being mistakenly solely attributed to a lack of plausibility or explanatory power of Embodied Cognition claims.

The implications of the potential effects of computational metaphors on our understanding of cognition, theories of cognition, and specifically Embodied Cognition are noteworthy for a couple of reasons. First, they are especially important to keep in mind and potentially nefarious because Embodied Cognition theories are relatively new theories of cognition compared to Computationalist theories. And the effects of conceptual metaphors are particularly germane to discussions in which one is pitting a theory like Computationalism, which is accompanied by conventional, well-entrenched, and foundational metaphors against newer theories, like Embodied Cognition—which lack such metaphorical support. Because of the crucial role that metaphors play in learning and understanding, a lack of embodiment-friendly metaphors means that Embodied Cognition theories lack crucial tools to communicate the content and plausibility of their claims. This lack can undermine people's ability to fully understand and appreciate the plausibility and explanatory power of Embodied Cognition, especially at the points that it is most radical and clearly opposed to Computationalist theories of cognition. Petrie & Oshlag attest to this when they say that metaphors are "one of the central ways of leaping the epistemological chasm between old knowledge and radically new knowledge" (1993: 440). As does Amin who explains that an important, underappreciated "aspect of conceptual change is the revision of metaphorical mappings between source and target domains" (2018: 15). Development and intentional use of embodiment-friendly metaphors for cognition and cognitive processes is an overlooked but important way in which Embodied Cognition theorists could further make the case for Embodied Cognition, which is especially important because of its relative novelty and degree of opposition to more entrenched theories of cognition.

Second, insofar as these effects of computational metaphors are partially responsible for some of the resistance to Embodied Cognition, Embodied Cognition can provide a particularly compelling account of some of the resistance it faces. Despite this, discussions and defenses of Embodied Cognition have, thus far, failed to engage with or even note the potential role of (conceptual, embodied) computational metaphors in debates about cognition. Ultimately, this may, ironically, come from a failure to fully appreciate some of the implications of Embodied Cognition—the direct and robust influence of sensorimotor states and processes on cognition through embodied, conceptual metaphors—on "the Embodied Cognition debate" itself. The presence and effects of computational metaphors are largely overlooked as a result of pervasive assumptions about cognition according to which concepts are not embodied, and the rational processes we employ in argument evaluation aren't susceptible to arational, embodied influences like metaphors. Ironically, many of these assumptions are likely grounded in a computational view of the brain—according to which one takes in data and executes a set of specific programs or instructions to process it—which leaves little room for bounds or influences on this process that are not articulable in terms of the incoming data, programs, or underlying machinery involved in this processing. In contrast, these embodied influences are highlighted and accounted for in Embodied Cognition accounts of conceptual processing. In fact, these embodied mechanisms and the mechanisms by which they impact us, serve as clear instances of Embodied Cognition.[43] In other words, some of the mechanisms *highlighted by* and *uniquely accounted for* by Embodied Cognition contribute to understanding and evaluation of, and ultimately *resistance against* Embodied Cognition.

This ultimately contributes to the explanatory power of Embodied Cognition—insofar as it is able to explain the source of some of the resistance it faces as well as, relatedly, some of the apparent cognitive phenomena often cited as posing a particular challenge for it. Computational metaphors, insofar as they provide our main conceptual framework for understanding cognition, likely impact not just our understanding of cognition, but also our experience of our own cognition and cognitive processes. It may be the case that the way that we conceptualize, and seemingly experience, our own abstract thoughts—e.g. philosophical conceptualization and reasoning—as the kinds of things that are not amenable to explanation through embodied cognition is itself more deeply formed by our computational conceptual framework than we realize, and less dictated by the 'raw form' of such thoughts themselves. While of course, this does not fully undermine resistance against Embodied Cognition, it can serve to undermine or at least call into question some of its presumed force. Thus, in short, Embodied Cognition theorists ought to more often bring some of the implications of Embodied Cognition to bear on their explanations and defenses of Embodied Cognition, as I have done here, because they are uniquely well-positioned to address and leverage this aspect of the debate. Furthermore, they also ought to be more intentional in their use of metaphors for cognition and in developing and utilizing embodiment-friendly metaphors for cognition because of their relationship to the underlying conceptual framework(s) in play.

Conclusion

In summary, I articulated the picture of conceptual processing presented by Embodied Cognition theorists—focusing specifically on the role of conceptual metaphors—and then drew on this to argue for the centrality of conceptual and embodied metaphors in computational statements. I then demonstrated how these computational metaphors may shape and ultimately bias how we under-

43. And a more general advantage of embodied cognition accounts may be that it can provide more of an account of intuitive resistance to arguments. Additionally, note that even the presumed distinction between "rational" and "arational" (or embodied) influences on cognition is challenged by Embodied Cognition.

stand cognition and evaluate Embodied Cognition theories. In doing so, I have not taken the standard approach of defending Embodied Cognition from specific content-focused objections; rather, I have focused on providing an account of some of the intuition-based resistance that it faces. Insofar as we take Embodied Cognition's claims of embodied influence on both our cognition and our *understanding of* cognition seriously, we ought to address the potential for these influences to animate and inform various components of the 'Embodied Cognition debate'. Additionally, the effects of embodied metaphors on philosophical reasoning overall are woefully underappreciated and under-investigated—thus this is an area in which Embodied Cognition can draw attention to and provide compelling accounts of the arational and often unnoticed influences on cognition.

Acknowledgments

Thanks to Ted Warfield, Peter Finocchiaro, Allison Krile Thornton and her Honors Seminar students at University of South Alabama, students in my Philosophy of Mind courses at Hope College, and Michael Rauschenbach for comments on various versions of this paper.

References

Adbo, Karina and Keith Taber (2009). Learners' Mental Models of the Particle Nature of Matter: A study of 16-year-old Swedish science students. *International Journal of Science Education*, *31*(6), 757–786.

Ahmady, Soleiman, Minoo Yaghmaei, Maliheh Arab, and Alireza Monajemi (2016). Metaphor in Education; Hidden but Effective. *Journal of Medical Education for Future Demands*, *15*(1), 52–57.

Alibali, Martha and Mitchell Nathan (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences*, *21*(2), 247–286.

Amin, Tamer (2018). Conceptual Metaphor and the Study of Conceptual Change: Research synthesis and future directions. In Tamer Amin, Fredrik Jeppsson, and Jesper Haglund (Eds.) *Conceptual Metaphor and Embodied Cognition in Science Learning* (234–260). Routledge.

Amin, Tamer, Fredrik Jeppsson, and Jesper Haglund (Eds.) (2018). *Conceptual Metaphor and Embodied Cognition in Science Learning*. Routledge.

Anderson, Michael (2010). Neural reuse: A fundamental organizational principle of the brain. *Behavioral and Brain Sciences*, *33*(4), 245–266.

Anderson, Michael (2014). *After Phrenology: Neural Reuse and the Interactive Brain*. MIT Press.

Anderson, Michael (2016). Précis of After Phrenology: Neural Reuse and the Interactive Brain. *Behavioral and Brain Sciences*, *39*(e120).

Barsalou, Lawrence (2003a). Situated Simulation in the Human Conceptual System. *Language and Cognitive Processes 18*(5/6), 513–562.

Barsalou, Lawrence (2003b). Abstraction in Perceptual Symbol Systems. *Philosophical Transactions of the Royal Society of London B: Biological Sciences 358*(1435): 1177–1187.

Barsalou, Lawrence (2009) Simulation, Situated Conceptualization, and Prediction. *Philosophical Transactions of the Royal Society of London B: Biological Sciences 364*(1521): 1281–1289.

Barsalou, Lawrence (2016). On Staying Grounded and Avoiding Quixotic Dead Ends. *Psychonomic Bulletin & Review*, *23*(4), 1122–1142.

Binder, Jeffrey and Rutvik Desai (2011) The neurobiology of semantic memory. *Trends Cogn. Sci. 15*(11), 527–536.

Bleakley, Alan (2017). *Thinking with Metaphors in Medicine: The State of the Art.* Routledge.

Bookheimer, Susan (2002) Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. *Annu. Rev. Neurosci. 25*(1), 151–188.

Boulenger, Véronique, Yury Shtyrov, and Friedemann Pulvermüller (2012) When do you grasp the idea? MEG evidence for instantaneous idiom understanding. *Neuroimage 59*(4), 3502–3513.

Bowdle, Brian and Dedre Gentner (2005). The Career of Metaphor. *Psychological Review* 112.1: 193.

Bowes, Andrea and Albert Katz (2015). Metaphor creates intimacy and temporarily enhances theory of mind. *Memory & Cognition*, 43(6), 953–963.

Boyd, Richard (1993). Metaphor and Theory Change. In Andrew Ortony (Ed.), *Metaphor and Thought* (481–532). Cambridge University Press.

Brookes, David and Eugenia Etkina (2007). Using conceptual metaphor and functional grammar to explore how language used in physics affects student learning. *Physical Review Special Topics-Physics Education Research*, *3*(1), 010105.

Brookes, David and Eugenia Etkina (2009). "Force," ontology, and language. *Physical Review Special Topics-Physics Education Research*, *5*(1), 010110.

Brookes, David and Eugenia Etkina (2015). The importance of language in students' reasoning about heat in thermodynamic processes. *International Journal of Science Education*, *37*(5–6), 759–779.

Casasanto, Daniel (2009). When is a linguistic metaphor a conceptual metaphor? In V. Evans and S. Pourcel (Eds.), *New Directions in Cognitive Linguistics (24)* (127–145). John Benjamins Publishing Co.

Chandler Jesse, Reinhard David, Schwarz Norbert (2012). To judge a book by its weight you need to know its content: Knowledge moderates the use of embodied cues. *Journal of Experimental Social Psychology*, *48*(4), 948–952.

Chemero, Anthony (2011). *Radical Embodied Cognitive Science*. Cambridge: MIT Press.

Chi, Michelene, James Slotta, and Nicholas De Leeuw (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction*, *4*(1), 27–43.

Citron, Francesca and Adele Goldberg (2014) Metaphorical sentences are more emotionally engaging than their literal counterparts. *J. Cogn. Neurosci. 26*(11), 2585–2595.

Clark, Andy (2008). *Supersizing the mind: Embodiment, Action, and Cognitive Extension*. Oxford University Press.

Close, Hunter, and Rachel Scherr (2018). Enacting Conceptual Metaphor through Blending: Learning activities embodying the substance metaphor for energy. In Tamer Amin, Fredrik Jeppsson, and Jesper Haglund (Eds.), *Conceptual metaphor and embodied cognition in science learning* (107–134). Routledge.

Coello, Yann and Martin Fischer (2016). *Perceptual and Emotional Embodiment (Foundations of Embodied Cognition Vol. 1).* Routledge/Taylor & Francis Group.

Cooper, Richard and Tim Shallice (2011). *The Organisation of Mind*. Oxford University Press.

Correia, Vasco (2011). Biases and fallacies: the role of motivated irrationality in fallacious reasoning. *Cogency 3*(1), 107–126.

Crippen, Matthew and Jay Schulkin (2020). *Mind Ecologies: Body, Brain, and World*. Columbia University Press.

Dayan, Peter and Laurence Abbott (2005). *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. MIT Press.

Dua, Andre *et al.* (2022). Americans are embracing flexible work—and they want more of it. Retrieved from: https://www.mckinsey.com/industries/real-estate/our-insights/americans-are-embracing-flexible-work-and-they-want-more-of-it

Dweck, Carol (2008). Can Personality Be Changed? The Role of Beliefs in Personality and Change. *Current Directions in Psychological Science 17*(6), 391–394.

Ervas, Francesca, Elisabetta Gola, and Maria Grazia Rossi (2018). Argumentation as a Bridge Between Metaphor and Reasoning. In *Argumentation and Language—Linguistic, Cognitive and Discursive Explorations* (153–170). Springer, Cham.

Finley, Kate (under review1) *Metaphors for the Mind: Reshaping experiences of psychopathology & suffering.*

Finley, Kate (under review2) *Memory Metaphors, Mnemonic Humility, and Neurodiversity: Illuminating conceptions and experiences of recollection.*

Finsen, Andreas, Gerard Steen, and Jean Wagemans (2019). An argumentative reconstruction of the computer metaphor of the brain. *Journal of Argumentation in Context*, *8*(3), 317–335.

Fodor, Jerry (1980) Methodological solipsism considered as a research strategy in cognitive psychology. *Behavioral and Brain Sciences 3(*1), 63–73.

Fodor, Jerry (2000). *The Mind Doesn't Work that Way: The Scope and Limits of Computational Psychology*. MIT Press.

Fodor, Jerry (2008). *LOT 2: The Language of Thought Revisited*. Oxford University Press.

Gallagher, Shaun (2017). *Enactivist Interventions: Rethinking the Mind*. Oxford University Press.

Gallistel, Charles and Adam King (2011). *Memory and the Computational Brain: Why Cognitive Science Will Transform Neuroscience*. Wiley.

Gauthier, Jon, João Loula, Eli Pollock, Tyler Brooke Wilson, and Catherine Wong (2019). From mental representations to neural codes: A multilevel approach. *Behavioral and Brain Sciences*, *42*.

Gentner, Dedre, and Brian Bowdle (2001). Convention, form, and figurative language processing. *Metaphor and Symbol, 16,* 223–247.

Gibbs Jr., Raymond (2011). Evaluating Conceptual Metaphor Theory. *Discourse Processes*, *48*(8), 529–562.

Gibbs Jr., Raymond and Teenie Matlock (2008). Metaphor, imagination, and simulation: Psycholinguistic evidence. In Raymond Gibbs, Jr. (Ed.), *The Cambridge Handbook of Metaphor and Thought* (161–176). Cambridge University Press.

Glucksberg, Sam (2003). The psycholinguistics of metaphor. *Trends in Cognitive Sciences*, *7*(2), 92–96.

Glucksberg, Sam, Matthew McGlone, and Deanna Manfredi (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language*, *36*(1), 50–67.

Goldin-Meadow, Susan (2005). *Hearing Gesture: How Our Hands Help Us Think.* The Belknap Press of Harvard University Press.

Goldin-Meadow, Susan Cook, and Zachary Mitchell (2009). Gesturing Gives Children New Ideas About Math. *Psychological Science 20(*3), 267–272.

Goldinger, Stephen, Megan Papesh, Anthony Barnhart, Whitney Hansen, and Michael Hout (2016). The poverty of embodied cognition. *Psychonomic Bulletin & Review*, *23*(4), 959–978.

Goldstone, Robert, Tyler Marghetis, Erik Weitnauer, Erin Ottmar, and David Landy (2017). Adapting perception, action, and technology for mathematical reasoning. *Current Directions in Psychological Science*, *26*(5), 434–441.

Hampe, Beate (Ed.) (2017). *Metaphor: Embodied Cognition and Discourse.* Cambridge University Press.

Haugeland, John (1981). *Semantic Engines.* MIT Press.

Hebb, Donald (1949) *The Organization of Behavior: A Neuropsychological Theory.* Wiley.

Herrera, Juan and Eric Riggs. (2013). Relating Gestures and Speech: An analysis of students' conceptions about geological sedimentary processes. *International Journal of Science Education*, *35*(12), 1979–2003.

Holyoak, Keith (2001). Psychology. In Robert Wilson and Frank Keil (Eds.), *The MIT Encyclopedia of the Cognitive Sciences*. MIT Press.

Hostetter, Autumn and Martha Alibali (2008) Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review 15*(3), 495–514.

Hutto, Daniel and Erik Myin (2017). *Evolving Enactivism: Basic Minds Meet Content*. MIT press.

Jeppsson, Fredrik, Jesper Haglund, Tamer Amin, and Helge Strömdahl (2013). Exploring the Use of Conceptual Metaphors in Solving Problems on Entropy. *Journal of the Learning Sciences, 22*(1), 70–120.

Jorati, Julia (2019). Embodied Cognition Without Causal Interaction in Leibniz. In Dominik Perler and Sebastian Bender (Eds). *Causation and Cognition in Early Modern Philosophy* (252–273). Routledge.

Katz, Albert and Tamsen Taylor (2008). The Journeys of Life: Examining a Conceptual Metaphor with Semantic and Episodic Memory Recall. *Metaphor and Symbol*, *23*(3), 148–173.

Kövecses, Zoltán (2008). Conceptual metaphor theory: Some criticisms and alternative proposals. *Annual Review of Cognitive Linguistics*, *6*(1), 168–184.

Lakoff, George (1993). The Contemporary Theory of Metaphor. In Andrew Ortony (Ed.) *Metaphor and Thought* (202–251). Cambridge University Press.

Lakoff, George and Mark Johnson (2008). *Metaphors We Live By*. University of Chicago Press.

Lakoff, George and Rafael Núñez (2000). *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics Into Being* (Vol. 6). Basic Books.

Luhrmann, Tanya (2011). Toward an Anthropological Theory of Mind. *Suomen Antropologi: Journal of the Finnish Anthropological Society*, *36*(4), 5–69.
Maley, Corey (2011). Analog and digital, continuous and discrete. *Philosophical Studies*, *155*, 117–131.
Marcus, Gary (2015). Face It, Your Brain Is a Computer. *New York Times*, June 27, 2015.
Meier, Brian and Michael Robinson. (2004). Why the Sunny Side Is Up: Associations Between Affect and Vertical Position. *Psychological Science*, *15*(4), 243–247.
Nemirovsky, Ricardo, Chris Rasmussen, George Sweeney, and Megan Wawro (2012). When the Classroom Floor Becomes the Complex Plane: Addition and Multiplication as Ways of Bodily Navigation. *Journal of the Learning Sciences*, *21*(1), 287–323.
Nie, Jing-Bao, Adam Gilbertson, Malcolm de Roubaix, Ciara Staunton, Anton van Niekerk, Joseph Tucker, and Stuart Rennie (2016). Healing Without Waging War: Beyond Military Metaphors in Medicine and HIV Cure Research. *The American Journal of Bioethics*, *16*(10), 3–11.
Niebert, Kai and Harald Gropengiesser (2015). Understanding Starts in the Mesocosm: Conceptual metaphor as a framework for external representations in science teaching. *International Journal of Science Education*, *37*(5–6), 903–933.
Niebert, Kai, Sabine Marsch, and David Treagust (2012). Understanding needs embodiment: A theory-guided reanalysis of the role of metaphors and analogies in understanding science. *Science Education*, *96*(5), 849–877.
Patterson, Karalyn, Peter Nestor, and Timothy Rogers (2007) Where do you know what you know? The representation of semantic knowledge in the human brain. *Nat. Rev. Neurosci. 8*(12), 976–987.
Perrin, Andrew, and Madhu Kumar (2019). About three-in-ten U.S. adults say they are 'almost constantly' online. Retrieved from Pew Research Center. Website: https://www.pewresearch.org/short-reads/2021/03/26/about-three-in-ten-u-s-adults-say-they-are-almost-constantly-online/
Perrott, David, Dedre Genter, and Galen Bodenhausen (2005). Resistance is futile: The unwitting insertion of analogical inferences in memory. *Psychonomic Bulletin & Review*, *12*(4), 696–702.
Petrie, Hugh and Rebecca Oshlag (1993). Metaphor and Learning. In Andrew Ortony (Ed.), *Metaphor and Thought* (579–609). Cambridge University Press.
Piccinini, Gualtiero (2008). Computation without Representation. *Philosophical Studies*, *137*(2), 205–241.
Piccinini, Gualtiero (2009). Computationalism in the Philosophy of Mind. *Philosophy Compass*, *4*(3), 515–532.
Piccinini, Gualtiero (2010). The Mind as Neural Software? Understanding Functionalism, Computationalism, and Computational Functionalism. *Philosophy and Phenomenological Research*, *81*(2), 269–311.
Piccinini, Gualtiero and Sonya Bahar (2013). Neural Computation and the Computational Theory of Cognition. *Cognitive Science*, *37*(3), 453–488.
Pulvermüller, Friedemann (2013). How neurons make meaning: brain mechanisms for embodied and abstract-symbolic semantics. *Trends in Cognitive Sciences*, *17*(9), 458–470.
Pulvermüller, Friedemann (2018). Neural reuse of action perception circuits for language, concepts and communication. *Progress in Neurobiology*, *160*, 1–44.

Pylyshyn, Zenon (1993). Metaphorical imprecision and the "top-down" research strategy. In Andrew Ortony (Ed.), *Metaphor and Thought* (543–559). Cambridge University Press.

Rainer, Yvonne (1961). The Mind is a Muscle. *Work*, *73*(63), 4.

Raja, Vicente, and Michael Anderson, Michael (2019). Radical Embodied Cognitive Neuroscience. *Ecological Psychology*, *31*(3), 166–181.

Ralston, Anthony, Edwin Reilly, and David Hemmendinger (Eds.). (2003). *Encyclopedia of Computer Science, 4th edition*. Wiley.

Rapaport, William (2018). What is a Computer? A Survey. *Minds and Machines*, *28*(3), 385–426.

Richards, Blake and Timothy Lillicrap (2022). The Brain-Computer Metaphor Debate Is Useless: A Matter of Semantics. *Frontiers in Computer Science, 4*, 810358.

Robins, Shani, and Richard Mayer (2000). The Metaphor Framing Effect: Metaphorical Reasoning About Text-Based Dilemmas. *Discourse Process*, *30*(1), 57–86.

Rogers, Timothy, Ralph Lambon, Peter Garrard, Sasha Bozeat, James McClelland, John Hodges, and Karalyn Patterson (2004). Structure and Deterioration of Semantic Memory: A Neuropsychological and Computational Investigation. *Psychological Review*, *111*(1), 205.

Schank, Roger (2014) *Conceptual Information Processing*. North Holland.

Scherr, Rachel, Hunter Close, Eleanor Close, Virginia Flood, Sarah McKagan, Amy Robertson, Lane Seeley, Michael Wittmann, and Stamatis Vokos (2013). Negotiating energy dynamics through embodied action in a materially structured environment. *Physical Review Special Topics-Physics Education Research*, *9*(2), 020105.

Schneider, Susan (2011). *Language of Thought. A New Philosophical Direction*. MIT Press.

Searle, John R. (1990). Is the Brain a Digital Computer?. In *Proceedings and Addresses of the American Philosophical Association*, *64*(3), 21–37.

Shapiro, Lawrence (2010). Embodied Cognition. In Eric Margolis, Richard Samuels, and Stephen P. Stich (Eds.), *Oxford Handbook of Philosophy and Cognitive Science* (118–146), Oxford University Press.

Shatz, Carla (1992). The Developing Brain. *Scientific American*, *267*(3), 60–67.

Shea, Nicholas (2018). *Representation in Cognitive Science*. Oxford University Press.

Simon, Herbert (1996) *The Sciences of the Artificial, Third Edition*. MIT Press.

Solomon, Karen, and Lawrence Barsalou (2001). Representing Properties Locally. *Cognitive Psychology*, *43*(2), 129–169.

Sprevak, Mark and Matteo Colombo (2019) *The Routledge Handbook of the Computational Mind*. Routledge.

Tate, Tyler (2020). Your Father's a Fighter; Your Daughter's a Vegetable: A Critical Analysis of the Use of Metaphor in Clinical Practice. *Hastings Center Report*, *50*(5), 20–29.

Thagard, Paul (2005). *Mind: Introduction to Cognitive Science (Second Edition).* MIT Press.

Thagard, Paul (2019). *Mind-Society: From Brains to Social Sciences and Professions (Treatise on Mind and Society).* Oxford University Press.

Thibodeau, Paul, Anna Winneg, Cynthia Frantz, and Stephen Flusberg (2016). The mind is an ecosystem: Systemic metaphors promote systems thinking. *Metaphor and the Social World*, *6*(2), 225–242.

Thibodeau, Paul, and Frank Durgin (2008). Productive figurative communication: Conventional metaphors facilitate the comprehension of related novel metaphors. *Journal of Memory and Language*, *58*(2), 521–540.

Thibodeau, Paul and Lera Boroditsky (2011). Metaphors We Think With: The Role of Metaphor in Reasoning. *PLoS One 6*(2), e16782.

Thibodeau, Paul and Lera Boroditsky (2013). Natural Language Metaphors Covertly Influence Reasoning. *PLoS One 8*(1), e52961.

Van Gelder, Tim (1995). What Might Cognition Be, If Not Computation? *The Journal of Philosophy*, *92*(7), 345–381.

Wilson, Andrew, and Sabrina Golonka (2013). Embodied cognition is not what you think it is. *Frontiers in Psychology*, *4*(58), 1–13.

Wilson, Robert and Lucia Foglia (2017). Embodied Cognition. In Edward N. Zalta, Uri Nodleman (Eds.), *The Stanford Encyclopedia of Philosophy,* Spring 2017 edition, URL=<https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/>