Reevaluating Wilson's Six Views of Embodied Cognition

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Abstract

It has been roughly a decade and a half since the publication of Wilson's (2002) "Six Views of Embodied Cognition," a now seminal review paper assessing six tenets, which at the time were widely espoused within embodied research and theory. Since 2002, there has been an abundance of new research within the domain of embodied cognition, and a reassessment of these six views is long overdue. The following paper reevaluates the six claims primarily using research published after Wilson's article, focusing on embodied phenomena relating to the executive functions of working memory, inhibitory processes (i.e., selective attention and self-regulation), and cognitive flexibility; three domains imperative to the top-down processes of abstract reasoning, planning, and problem solving. As several of the views addressed by Wilson are absolute assertions regarding the nature of cognition (e.g., "cognition is for action"), it follows that they should be readdressed using evidence from cognitive domains encompassing functions that are not conspicuously related to motor action. Additionally, there has been a surprising amount of research exploring embodied effects within the human number sense, spanning topics from numerical spatial associations to the role of motor systems in arithmetic ability. Some embodied findings from the domain mathematical cognition are covered in this review, as numerical abilities are often reliant largely on executive functions and do not overtly have a high level of motor reliance. Relevant research from cognitive neuroscience is assessed in support of findings from the behavioral literature, as neurological evidence has served to form a more unified theory about the interplay between lower order motor systems and more complex cognitive ones.

Introduction

In 2002, Margaret Wilson wrote a seminal paper titled "Six views of embodied cognition," in which she outlined six fundamental tenets of the then relatively recent field of embodied cognition. This important review of the limited embodied literature assessed the evidence supporting the six views and gave a critique of each view's usefulness as a guiding principle for researchers endeavoring to explore the complex and often bewildering interplay between cognition and lower order motor-based systems of the brain. A more detailed explication of the six views will be given later in this review, but in short, Wilson's views are as follows: (1) cognition is situated, (2) cognition is time pressured, (3) we off-load cognitive work onto our environment, (4) the environment is part of our cognitive system, (5) cognition is for action, (6) offline cognition is body based. Wilson herself was not entirely convinced by all of the six views, but presented her paper as a review of six major trends found within the literature of the time that guided the underlying assumptions of embodied research.

Since the publication of these six views nearly a decade and a half ago, Wilson's article has been cited over eight-hundred times, and is still considered to be an integral piece of literature within the domain of embodied cognition. Given the abundance embodied research published in the last two decades, it is an opportune time to reassess the efficacy of Wilson's treatise in light of new research. Is there now more sufficient evidence to particularly support or refute the six tenets, or has recent data just added more ambiguity to the discussion? The following review will reassess Wilson's six views, giving particular attention to evidence from tasks and cognitive domains under the umbrella of executive function (i.e., functions reliant on working memory and attention). Further, relevant neurological evidence bolstering or refuting the behavioral evidence from the cognitive domain will also be assessed in order to bridge the conceptual understanding of the interplay between higher-order cognitive and simpler motor based systems.

A surprising amount of research exploring embodied effects within the human number sense has also been published since 2002. These works have spanned topics from numerical spatial associations to the role of motor systems in arithmetic ability. Many embodied findings from the domain of mathematical cognition are covered in this review as well, as numerical abilities are often reliant largely on executive functions and because the various phenomena within the domain of mathematical cognition do not (at first glance) typically appear to have a high amount of reliance on motor systems.

The term executive function (EF) has been used to describe a wide array of cognitive processes including attention, working memory, inhibitory control, abstract reasoning, problem solving, emotional regulation, mental simulation and planning (Diamond, 2013; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). It is fairly evident to even the non-psychologist that these systems are critical for healthy daily life, and relationships have been found between executive function and many factors including an abundance of mental health topics (depression: Tavares, 2007; addiction: Baler & Volkow, 2006; personality disorders: Barch, 2005, Fairchild et al., 2009, Penadés et al., 2007), physical health (Crescioni et al., 2001, Miller, Barnes, & Beaver, 2011), overall life satisfaction (Brown & Landgraf, 2010; Davis, Marra, Najafzadeh, & Lui-Ambrose, 2010), reading and math achievement (Borella, Carretti, & Pelgrina, 2010; Duncan et al., 2007), and career success (Bailey, 2007). Despite the pervasiveness of executive function as a construct across domains of inquiry and its crucial importance to our lives, it is still tricky to find a consensus on how to operationalize the term.

While there still exists a great deal of debate as to what the precise factors and underlying neural networks comprising executive function are, some researchers have distilled EF down to three main constructs: (1) inhibition, which includes selective attention and self-regulation (2) working memory, and (3) cognitive flexibility, considered to be linked to creativity (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). From these three, the more complex executive functions can arise including reasoning, planning, and problem solving. Despite this simpler three category description of executive function, there still exists a further disagreement among some researchers about the distinction between the constructs of executive attention (falling under the inhibition category) and working memory (Baddeley, 1991, 2001; Kane, Bleckley, Conway, & Engle, 2001), and evidence exists that the two are closely related both functionally and neurologically (Petersen & Posner, 2012). Some have even characterized the constructs as one and the same (Engle, 2002).

For the purposes of this review, executive function will be loosely operationalized using the three system approach (attention/inhibition, working memory, cognitive flexibility), with emphasis given to topics under this three system umbrella including more complex functions like reasoning and learning. More pragmatically, the functions that will be discussed are the general cognitive abilities used by humans and other organisms for the purpose of day-to-day function and survival; this cruder operationalization has also been used by some researchers (Koziol, Budding, & Chidekel, 2012; Miller, 2007). Regardless of how one defines EF, it is without a doubt a paramount feature of human cognition, and as such, is an apt domain from which to reassess Wilson's six views.

View 1: Cognition is situated

The first of Wilson's six claims is that cognition is a situated activity. What this essentially means is that cognition occurs in the context of receiving task appropriate inputs and produces relevant outputs. While any task is being carried out, cognition is still being affected by incoming sensory streams, and we produce and execute new motor actions concurrently with this incoming stream. Giving a lecture, driving a vehicle, or cooking a meal are all essentially situated activities in this view. Note here, what is excluded from this definition. While a vast array of our day to day actives and functions are indeed situated, there are many cognitive activities that occur in an "offline" sense, not meeting the situated requirement of task relevant input and output. Mentally simulating your lecture, planning your route prior to a drive, or keeping a list of cooking ingredients to be purchased in your working memory are all non-situated functions, particularly if these activities are being simulated outside of a context in which immediate action can be taken upon them.

The fact that we can abstract so readily without direct sensory input via mental representations in an offline fashion is arguably one of the defining features of human cognition. As such, this is a clear counterfactual to the those that hold a strict view that all cognition is situated. However, evolutionary theorists can make the argument that situated cognition is the foundation upon which higher order offline systems function. Before later human development, much of our mental activities were dedicated to direct response to environmental pressures (e.g., foraging for food, avoiding predators, reacting to weather conditions). Presumably, the function of temporal or spatial displacement was a later byproduct of a more complex cognitive system. Evolutionary arguments to this end have some differences but fundamentally are all in the same vein: the more successful early hominids would be those that can precipitate their food gathering needs and avoidance of predators or environmental dangers via offline cognition based means (Gover, 1996; Sterelny, 2008). Further, early hominid usage of tools clearly involves a great deal of offline representation in order to procure the materials necessary for production long before any basic motor actions can occur.

This view of cognition being a solely situated process for action did not bode well in 2002, and it has not held up in a strict form given new research. Examples abound of how not all cognition is situated (however it still may be body based, as we will discuss later). Despite this, there is literature that clearly demonstrates how older cognitive systems, those that at one point may have been purely situated, have a great deal of influence and interplay upon higher order systems that facilitate offline processes. One such example of this interplay is a phenomenon known as "hand altered vision" (Davoli & Tseng, 2015), in which having one's own hands in the visuospatial area affects cognitive performance, particularly in cognitive tasks requiring executive function. That is, merely being able to see one's own hands while completing a cognitive task, one not requiring the use of the hands, is enough to alter our performance, sometimes to our benefit, sometimes not. This was first discovered in a target detection task in which participants were more sensitive to finding a target if their hand was near to the visual array (Reed, Grubb, & Steele, 2006).

While it might not be readily apparent what this curious effect has to do with situated cognition, consider the following findings. Studies have found that recall performance in memory tasks is facilitated by hand placement (Davoli, Brockmole, & Goujon, 2012; Tseng, & Bridgeman, 2011) along with an array of attentional enhancements in other tasks (Cosman & Vecera, 2010; Davoli, & Brockmole, 2012; Linkenauger, Ramenzoni, & Proffitt, 2010; Vishton et al., 2007). Yet as mentioned, having the hands near the stimulus can causes decrements in particular scenarios, including tasks measuring visuospatial acuity (Gozli, West, & Pratt, 2012), semantic verification, and the classic Stroop paradigm (Davoli, Du, Montana, Garverick, & Abrams, 2010).

The research on hand altered vision consistently elicits two particular features. One, we have a predisposition to prioritizing our attention toward the space near the hand, essentially locking our mental focus to that area. Two, we are slower to disengage our attention from locations near the hands. These two mechanisms make sense when you consider how they might be an adaptive mechanism, allowing us to better focus our attention on tasks requiring fine motor function (like making a tool). As such, this interplay between viewing the hands and higher order executive systems is a byproduct of a system that evolved in a situated manner. Recall, the aforementioned hand altered effects occur regardless of whether the task requires the participant to use their hands, yet merely having them in visual space situates and elicits changes in cognitive performance. Alternatively, you might interpret hand altered vision being a byproduct of cognition preparing for motor action due to the hands being in visual space. As such, how do we disentangle non-situated instances of cognition from the situated, when even abstract thought can be influenced by systems designed to prepare us for action? The mechanism for this effect appears to be clusters of cross-modal neurons that code for both visual or proprioceptive awareness of the hands, but have some spillover into executive attention (di Pellegrino, Ladavas, & Farne, 1997; Làdavas, di Pellegrino, Farnè, & Zeloni, 1998).

Prior to Wilson's seminal paper, it was established that visual attention could be modulated by simple movements of the body. In one such study (Schindler & Kerkhoff, 1997) it was found that when keeping fixation constant, but altering the positon of the trunk of the body and/or head on the horizontal plane by as little as 20 degrees, performance decreased on both reading and line bisection tasks. Similarly, the orientation of the trunk of the body affects visual detection performance while moving in space, even when on a treadmill (Grubb, Redd, Bate, Garza, & Roberts, 2008). Regardless of the focal position of our gaze, we have a bias for the detection of objects directly in front of the body, perhaps as a byproduct of an early mechanism for the prevention of collisions while walking through space. One study has even revealed a bias toward objects ipsilateral to where we point our tongue in a challenging visual search task (Barnett-Cowan, Soeizi, & DeSouza, 2015). Consistent with hand-altered-vision findings, these studies demonstrate how attention is biased by the body even when no action is taken upon a target, further suggesting a situated influence of motor systems even in tasks not requiring any sort of bodily action.

A universal byproduct of the embodied (and perhaps situated) nature of our cognition is the use of gesture while speaking. While gesture undoubtedly serves a function as a secondary means of communication between speaker and audience, a curious finding from research into gesture is that congenitally blind speakers gesture to other blind listeners (Iverson, Goldin-Meadow, 2001), just as individuals with sight gesture while conversing on the telephone (Bavela, Gerwing, Sutton, & Prevost, 2008). Recent research has delved into the relationship between gesture and aspects of executive function including spatial reasoning and the learning of tasks that require spatial ability.

In a task designed to examine the effect of gesture on spatial reasoning, researchers had participants complete the classic Tower of Hanoi task (Beilock & Goldin-Meadow, 2010). After their first attempt at the task, participants took a short break and were instructed to describe how they completed the problem, using gesture to help explain. For one group of participants in the second block of tower solving, researchers adjusted the weight of the smallest disk in the tower, such that it required two hands to be lifted. What they found was participants who used gesture indicating one-handed manipulation of the smallest disk in their first block showed performance decrements in the second block if the weight of the small disk had been adjusted. The participants in the condition where the weight had not been switched showed no such difference. The implication of this finding is that our motor actions, as well as gesture as a proxy for action, have influence over our representation of physical properties of objects. When a gesture, and underlying mental representation of that gestured action, is no longer congruent with the action required within a task, problem solving is hindered. Here, it seems that our representations of a problem can become further situated or grounded in distinct physical properties conveyed by gesture. These act as a further simulation of a task, strengthening and further situating the representation.

Other work has examined the role that gesture plays in children's development, including a topic even Piaget overlooked, the involvement of gesture through the Piagetian stages (e.g., the gestures children use when describing the water conservation task; Goldin-Meadow, 2015). Gesture during our early developmental stages is produced spontaneously without prompting, and emerges early in our development, in tandem with our reasoning and language abilities, so it would stand to reason that the underlying linkages between cognition and motor systems is not a byproduct of later learning, but inherent to the very structure of our networks, a topic we will discuss in greater detail later. This early trajectory lends itself to gesture subserving numerous aspects of cognition, and its universality among humans has a pragmatic benefit in teaching procedural topics like mathematics (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2015).

Relatedly, researchers have examined the role of gesture in novel language learning with children, particularly in learning palindromes (i.e., words spelled the same forward or backwards; Wakefield & James, 2015). Here, children between the ages of 6 and 8 naïve to the concept of palindromes were taught the basic idea with or without the aid of gesture. They then were administered a post-test of made up palindromes in order to determine the effect of gesture on their understanding where they had to insert a missing letter into a palindrome (e.g., "ANIMI_A"). The results indicated that children who received gesture performed better on the post-test. While this task does not require a situated cognitive system perse, it does demonstrate that adding a situated component (i.e., gesture) aids in the understanding of abstract concepts. Similar types of facilitation have been found in adults, as individuals are more prone to gesture when describing a mental rotation problem if the task is more difficult, and subsequently perform better after describing the task while using gesture than without (Chu & Kita, 2011). Considering these gestural effects begin in childhood and persist into adulthood, it might be inferred that it is an inherent mechanism of our cognition to use gesture, which in turn situates the explanation and learning of abstract concepts in simulated motor expression.

Studies have established inherent spatial associations between the body and numerical magnitude, situating even our knowledge of number. The classic example is the Spatial–Numerical Association of Response Codes (SNARC) effect, in which we are faster to associate small numbers with our left hand, and larger numbers with our right (Dehaene, Bossini, Giraux, 1993). These associations extend beyond the hands however, as even posture can modulate estimates of size, evidenced by an embodied study in which participants had to estimate the size of the Eiffel Tower (Eerland, Guadalupe, & Zwann, 2011). In a clever experiment using a Wii balance board to manipulate how participants leaned in space, participants had to answer judgments of the height of buildings while slightly leaning to the right or left. Drawing on research examining our mental-number-line, and how we represent smaller numbers on the left and larger numbers on the right (Restle, 1970), the experimenters posited that participants would make smaller judgments of height when leaning slightly to the left, indicative of an interaction between this mental-number-line on our magnitude judgments. This was indeed what they found, with participants giving smaller estimates when leaning left. While their discussion was a reticent to posit the exact underlying mechanism for this finding, their results do contribute to the canon of evidence demonstrating the interaction between underlying cognitive representations of magnitude and the body, implying that even simple representations like the ordinal nature of numbers may be a situated phenomenon.

This lends itself to training paradigms designed to strengthen the spatial-numerical associations that may innately exist (Fischer, Moeller, Bientzle, Cress, & Nuerk, 2010). In one such example, researchers examined performance of children's number line estimation after two types of number line training procedures. In one group, children were taught using a large dance mat connected to a computer which required them to physically move in space to register number line estimations. In a second group, the children completed a smaller version of the task on a tablet. The results indicated that after physical spatial training, children's number line estimation was significantly improved over those who only engaged in the tablet based training. This could be indicative of an enhancement of our underlying ordinal numerical system through physical training, or more conservatively, that taking the number line task out of the realm of abstraction and into the physical situated world facilitated better understanding and subsequent performance.

Relatedly, in a clever experiment designed to determine how the size of our bodies affects basic judgments of size, Banakou, Groten, and Slater (2013) had adult participants occupy a virtual child body through the use of virtual reality headsets in conjunction with motion capture suits. While in the virtual environment, the participants could examine their virtual selves in a mirror which would reflect their image based on the motion tracking of the capture suit the participant was wearing. In one condition, participants saw themselves in the mirror as full-sized adults, whereas in a separate condition, the mirror would reflect a body size much smaller and more child-like than their own. In either virtual body state, participants had to judge the physical size of virtual objects, and use corresponding hand gestures to indicate the actual size of the object. Critically, the experiment demonstrated that while occupying the virtual child body, participants were apt to overestimate the size of objects in their environment, seemingly emulating the how children might perceive the world as far larger than we do as adults. This seems to indicate that even basic judgments of magnitude are situated and influenced by physical properties of the body. We might expect that children's inexperience with the world would lend itself to inaccuracy in judgments of physical size or overestimation, however the finding that merely changing the visual representations of our own adult bodies can alter perceptions of magnitude seems to indicate that children's misjudgments may not be due to inexperience. Instead it is possible that their representations of space and magnitude are situated and in turn constrained by the size of their own bodies.

Collectively these studies exhibit many situated features of executive function and numerical processing. The basic fact that we can represent knowledge in an offline manner and conjure temporally or spatially displaced representations, representations irrelevant to immediate action, might be an immediate counter to the notion that all cognition is situated. However, it appears that many aspects of our cognition are at the very least heavily influenced by situated attributes via feedback of the body. As such, one might posit that cognition evolved out of a system that was previously situated. A more accurate view about the present nature of our cognition might be, "cognition is often situated" or even "most of our cognition is situated."

Further, you might consider purely abstract thought to be a counter to this notion that all cognition is situated. However here it might be pertinent to ask, from where does abstract thought arise? Do we not have to possess something concrete to abstract from? Jamrozik, McQuire, Cardillo, and Chatterjee (2016) discuss the relationship between abstract concepts and metaphor, and how metaphor ultimately brings us back to the usage of embodied representations. Suppose an individual is learning about the idea of negotiation. The metaphor "negotiation is a tool" might aid in understanding that it can be used to achieve a goal.

Here, the term tool might infer a social goal or objective between multiple parties, but even the notion of tool is just a layer of abstraction above its most basic usage; a handheld object that aids in or enables a specific physical function. Jamrozik et al. posit that in these types of metaphors, sensorimotor simulation essentially underlies the metaphor's usage, but that with repeated practice, the metaphor can become sufficiently abstracted away from motor or sensory representations. The flexibility of our cognitive system allows for levels of abstraction that are certainly not situated in nature, but that may have at some point relied upon grounded simulations arising from situated experience.

View 2: Cognition is time pressured

An extension of the previous notion that cognition is situated is the assertion that cognition is time pressured. That is, in dealing with external factors via situated cognition, we must react to environmental factors in a quick manner, fleeing predators or executing precise motor actions to hunt or catch a fish. This seems rather evident at first glance and does not seem of particular importance outside of the discussion of situated cognition. However, it does play a large role in non-situated contexts as well. Wilson asserts that when circumstances require quick action or quick decisions, we often end up with a "representational bottle-neck." A common example that applies to this bottle neck notion is the classic "channel-capacity" analogy of cognition (Fitts, 1954; Hick, 1952), wherein our information processing systems have a limited capacity, much like the flow of information through a computer circuit or phone line. Time pressures constrain this capacity even further, and environmental limitations along with increasing perceptual loads can make it inefficient to construct fully formed representations of a situation, resulting in cheaper more efficient methods to generate appropriate actions in real-time.

This particular tenant of Wilson's six view has been discussed and debated the least in the past several decades. While many cognitive experiments consider the effects of time constraints on performance, the discussion of time pressure as a guiding principle in embodiment theory has received minimal attention. A recent review discussing embodied cognition from the perspective of event coding theories briefly addresses Wilson's view on time, noting that time pressure is not typically an inescapable issue in most modern scenarios (Hommel, 2015). Further, Hommel notes that because of this, we have the luxury of extending mental representations of action into offline simulation in order to more readily prepare. Studies to this end have examined this disconnect between immediate time constraints, and the preparatory simulation of action in motor areas prior to action, attempting to determine to what end we construct representations prior to action under time pressure (Kühn, Keizer, Rombouts, & Hommel, 2011; Leuthold, Sommer, Ulrich, 2004). Due to the sparseness of literature within this domain, it is inconclusive to what degree we engage in representational simulation prior to action, as it is likely highly task dependent. Preliminary ERP and fMRI data however seems to indicate that to some degree we are engaging in mental simulation of motor activity in preparation of physical action, and that this can slow immediate performance depending on the degree of simulation.

Time pressure is a self-evident restriction upon cognitive performance, and one might ask here, what about offline scenarios without any impending threat or urgency requiring action? Writing a research paper, making coffee, reading the paper are not as time pressured and can allow for a more leisurely approach to the stream of sensory input. In these scenarios, we can construct richer mental models and not be hindered by a "representational bottle-neck." The notion that cognition is time pressured, while clearly not being applicable in all scenarios can still guide our theoretical approaches to cognitive research. Imagine if our species had evolved in vacuum, an ecological scenario with abundant resources free of predation. It might follow that our physiology and subsequent cognition would be quite different. With less need for quick and immediate action, our cognitive system might have fewer resources linking executive systems to facilitate immediate motor actions; but perhaps a greater ability to construct richer mental representations in an offline manner, free from resource constraints.

While it might be a bit inane and arguably impossible to posit exactly what features we might possess under a less strenuous evolutionary prehistory, the point is, at some point in our development, human cognition was indeed more time pressured. Much like how the early occurrences of more situated scenarios gave rise to a cognitive system that is often influenced by the body, the often time pressured nature of our prehistory surely resulted in creating executive systems that allow for the construction of quick and dirty representations in order to facilitate immediate action. In this sense yes, cognition functions as if time pressured, however, not all scenarios require the same imperative time sensitivity. As such, as a guiding principle for embodied research, the time pressured nature of cognition may not be particularly insightful. Despite this, the ability to engage in mental representation, and even motor simulation, is subject to time constraints, which surely should be addressed on a case by case manner.

View 3: We off-load cognitive work onto the environment

As I sit in front of a computer, plugging away at this review paper, I have beside me a stack of research articles (several of which are laid out to specific pages for reference), a notepad and pencil with scribbling of relevant notes, and various pieces of detritus, coffee cups, food wrappers; the byproducts of graduate studies. Certainly I could not write a paper requiring nearly a hundred sources purely from memory; this task requires physical resources, outlines or bibliographies to refer to. Even after thoroughly reading various journals and book chapters to support my arguments, I must still return to them for reference. This is a basic example of Wilson's third notion, that we use our environment by leaving bits of information in it allowing us to refer to them when needed, consequently reducing our cognitive load and limiting bottle-necks. This can aid multiple aspect of our cognition, working memory load can be reduced by making a quick check-list of "to dos" for the immediate scenario, or it can aid a long-term requirement, like keeping a calendar of appointments for later months. With the more recent advent of cell phones, very few individuals bother to memorize new phone numbers, thus reducing requirements of our long-term memory for simple strings of necessary day-to-day knowledge.

Kirsh (1995) called this the "intelligent use of space," noting that experts at any task requiring multiple physical objects to be utilized will organize their environment to facilitate more efficient movement through the task. Whether this be a chef, moving ingredients and cooking utensils around a cutting board, a painter with brushes and pallet, or a student writing a paper, we organize our environment in a manner that reduces and expedites motor movements, subsequently reducing cognitive load. Relatedly Kirsh's idea of the intelligent use of space (and the opening vignette of this section), a recent study examined how we manipulate objects in space, and the influence of habit and efficiency on objects' placement during a writing task (Zhu & Risko, 2015). In two experiments, participants had to write for a period, and utilize various sources and writing utensils in their physical environment. In the easier writing task of the first experiment, participants showed a tendency to simply return objects to the area of their original placement, counterintuitive to this notion of our intelligent use of space. However, once writing demands were sufficiently challenging in experiment 2, participants disregarded original item placement and began organizing items in their space into configurations that facilitated less effortful motions. Zhu and Risko interpreted their results as indicating initial biases for habituated organizational tendencies, but that when under sufficient load or task demands, we begin to reshape organizational demands in line with task requirements.

Another task looked at this environmental offloading in a slightly more abstract manner. Gilbert (2014) conducted an online experiment (with a very large sample, N = 1996), examining how individuals use spatial cues to offload cognitive work to the environment, and how this offloading facilitates prospective memory. In a simple task, participants using Mechanical Turk had to drag circles outside of a box in which they were displayed. The circles were numbered 1-10 and in initial trials had to be simply dragged via mouse to the bottom of the box in numerical order. On particular trials however, participants would have to drag particular numbered circles to specific locations outside of the box (i.e., top, left, or right). The task allowed for some offloading of this prospective memory prior to each trial by permitting participants to pre-arrange the circles near the sides of the box that they needed to be dragged. Much like we might leave an object near a location so we remember to take it with us before leaving the house, the spatial location of where subjects placed the disk acted as a perceptual cue within the task. Additionally, the experiment had an interruption condition where the participants would complete arithmetic problems after dragging the disks. Across several variations of this task, the researchers found that participants were more likely to offload (i.e., use perceptual memory cues) under three conditions; if they received greater memory load caused by a secondary task, if there were more interruptions during the primary task, and if they were older. These findings demonstrate, unsurprisingly, that as cognitive load increases, we engage in more offloading and external assistance to aid prospective memory or future intentions. This practice is surely adaptive and further served older participants in their task with simple age related decline in prospective memory (Maylor, 2008).

Much like the aforementioned examples, Wilson notes that typical evidence supporting the notion that we offload work comes from tasks that are spatial in nature. However, it is not always necessary that off-loading need be spatial in nature, as we can offload in a symbolic manner as well, with physical objects or relations between objects representing one or more abstract concepts. However, consider internalized simulations as a form of offloading. As we will discuss in later sections, some theories propose a form of sensorimotor simulation when engaging in representation of physical actions. One might construe the construction of a memory palace or the usage of the Method of Loci as a form of offloading, albeit into representational realms. Both of these methods take information that is cognitively demanding and offload it into a familiar mental space that represents some physical realm with which we are sufficiently familiar. Could this be construed as another form of environmental offloading? Wilson herself did not address this matter, but it very well could serve as a proxy mechanism that relates to our predisposition to environmental offloading.

We certainly can and do offload cognitive work onto our environments. How well this serves as a guiding view to assess cognition is still up for debate. However, the notion itself might mean a very different thing since the publication of Wilson's original article. Considering the recent advent and widespread usage of smart phones, the idea of offloading cognition onto the physical world takes on a largely different meaning today than it did a decade and a half ago. Regardless off how actively we tend offload work onto the environment, there will likely be a burgeoning renewed interest in the topic in the coming years. Human augmentation or "biohacking" is a growing trend among fringe sects of online enthusiasts that integrate simple microcomputers onto their persons as an aid to their cognition. Also given the recent interest in augmented reality applications for smartphones, we are opening new avenues to facilitate environmental forms of cognitive offloading. Many of these technologies will be commonplace to cell phones in the coming years, and it is not inconceivable that we will soon be reconsidering where our cognitive system starts and ends relative to our technological devices.

View 4: The environment is part of the cognitive system

While there is sufficient evidence to clearly assert that the human body plays a role in cognition and can often augment performance, some theorists have made an even broader claim that not only is our body a part of the cognitive system, but that the environment itself a distributed cognitive system (Beer, 1995; Clark & Chalmers, 1998). That is not to say that the processes involved in cognition are occurring outside of the brain, but rather, that our cognition takes into account situational constraints and context, affecting cognition in real time. Our world is richly populated with stimuli, these stimuli give rise to internalized percepts, which in turn affect our cognitive systems. Thus, this view states that even within offline scenarios, we should consider environmental conditions' influence upon cognition. Those who argue this tenet would claim that within any scenario where we assess cognition, we must take into account situational constraints. Wilson discusses the boundaries of the term "system" as it applies to cognition, and argues that this notion of the environment as part of the cognitive system is dependent on what aspect of cognition you are examining. Through this view, we might consider some aspects of cognition to be open (i.e., open to the environment and possibly including environmental factors), while others are closed (i.e., separate and isolated from environmental influence).

The boundary of a system of interest should be established in a case-by-case manner (i.e., where does the boundary end for the system of interest? In the mind, body, or environment?), however using the environment as an aspect of cognition should be taken into consideration even in the simplest of experimental tasks. We already take minor environmental factors into consideration when administering reaction time tasks to individuals. We keep them free from external influence and try to isolate any potential environmental factors that could potentially contribute to variability across subjects in a task. Should they produce their responses to the task vocally or by mouse click? Will this affect reaction time? How close to the screen should they sit? Do we want them to sit still and just watch a stream of stimuli or should they interact with it? The very nature of basic experimental design questions implies a clear influence of the environment on our research participants, and in turn the theory we derive from their behaviors.

This line of questioning harks back to an earlier trend in psychology, the ecological approach championed by James Gibson. He coined the term "affordances" in his study of perceptual streams and how we utilize this information to take action (Gibson, 1979). An affordance refers to qualities of the physical world that facilitate our ability to act upon it. If one walks into a room containing a pizza and a couch, it is quite possible that we could sit on the pizza and eat the couch cushions, however the typical affordances of this scenario (as learned via previous experience) would lend most individuals to sit on the couch and eat the pizza. So while affordances are composed of what is possible, our memory and experience (reliant on cognitive factors) facilitate the appropriate action. An ecological approach would hold that one must consider affordances (and subsequently the environment) when considering cognition.

While considering the environment as a part of the cognitive system does not necessarily hold up to scrutiny in a literal sense, its premise can serve as a guiding constraint for researchers across multiple lines of inquiry. Clark (2006) lays out a framework that would support a lighter interpretation of the fourth view, particularly, that through interaction with our material world, our cognitive system becomes reliant on "hybrid" symbolic representations encompassing both language and symbolic representations existing in the environment. Citing Dehaene's (1999) work on the development of the human number sense, Clark notes that early in human number learning, for an entire year a child may understand that the word "three" is a number, despite not understanding the exact quantity to which three refers. It is only after we have encoded symbolic representations from objects in the environment (e.g., three toys) that we can understand the unique value of the integer three. While this notion might seem elementary, it serves a larger purpose. For example, looking at number, particularly the notion of discreet quantities, is of little use unless you have some symbolic representation or token to aid in distinguishing the different integers. Even after acquiring a symbolic representation of the discreet nature of integers, the knowledge that 100 is larger than 99 is largely abstract without some understanding that these values can exist in the environment. In some sense, the tokens, perceived in the environment, become some part of the cognitive system, even if only through representational means. By this logic, physical objects, gestures, diagrams, written language, even displays on our array of devices can be construed as environmental components of our cognitive system.

A less abstract exploration of this concept is found in a study examining the effects of tool usage on our perception of distance (Davoli, Brockmole, & Witt, 2012). In this study, participants pointed at objects within their environment using either a baton or a laser pointer, and made subsequent judgments of the objects' distance from themselves. While the authors did not discuss the topic of affordances, their experiment essentially manipulates the affordability of space via tool-usage. The results indicated an interesting compression of perceived space when participants pointed at the object with a laser pointer compared to the baton, even when the batteries were removed from the laser pointer and participants were told to imagine illuminating the target! The take-away from this study is that even imagined interactions (perhaps even imagined affordances) with the environment can have an impact on our spatial representations of them.

While the aforementioned study may be a weaker form of evidence supporting the notion that the environment exists as a portion of the cognitive system, it demonstrates that our perceived or imagined ability to interact with the environment greatly affects our representations. This may lend itself to larger theoretical notions about how cognition is scaffolded for the interaction with our environment, regardless of whether one considers the environment to be a part of the cognitive system. At the very least, it must be considered that cognition does not exist in a Cartesian vacuum, but rather, environmental constraints should be considered on a case-by-case basis as to their affect on cognition (i.e., Wilson's closed v. open systems).

View 5: Cognition is for action

The notion that cognition is for action is essentially the idea that all cognitive functions exist to support some adaptive motor function, and that even offline processes will eventually result in the execution of a motor action. This line of reasoning gained particular traction from lines of research examining memory and visual processing (Churchland, Ramachandran, & Sejnowski, 1994). Wilson notes that in understanding visual perception, the traditional assumption is that our visual system constructs an internal representation of the world, upon which our more developed cognitive areas can act upon. While the dorsal stream is generally seen as the "where" pathway in the brain, others have argued that this network should more appropriately be labeled as the "how" pathway (Goodale & Milner, 1992; Jeannerod, 1997). Rather than simply being a system that subserves the spatial component of visual processing, evidence has demonstrated that it also prepares us for motor action upon elements of this visual stream. Citing early research, Wilson notes that this network may account for the findings that certain types of visual input can prepare us for motor activity (Craighero, Fadiga, Umilta & Rizzolatti, 1996), and even the simple act of looking at tools can yield activation in the brain of areas associated with fine motor activity (Grafton, Fadiga, Arbib, & Rizzolatti, 1997). While the literature was sparse relating these visual systems to motor action in 2002, more recent evidence is largely in line with these notions.

While much of the "hand altered vision" research lends itself to this idea that cognition is for action, many other lines of inquiry seem to support this notion as well. Research has examined the effect of hand movement on the way we allocate visual attention (Festman, Adam, Pratt, & Fischer, 2013). In a novel study, participants had to move their hand to one of six spatial locations in order to trigger the presentation of a trial in a letter discrimination task. Discrimination performance improved when the right hand was moving toward the visual probe, seemingly indicating that the potential to act upon a target indicates our attentional allocation to it. This effect disappeared when the target appeared next to the static left hand, seeming to indicate that there is some larger potential biasing of effect of movement or initiated motor action.

Relatedly, studies have found we have a prioritization of memory for objects that we can interact with (Kirtley & Tatler, 2016). In a study designed to test this prioritization, participants entered a kitchen where twenty-one objects had been placed. Within the set of objects, seven were necessary for tea making, seven for making a sandwich and pouring juice, and a final seven relevant to a kitchen, but not pertinent to the two tasks. The participants were told they would have to complete one of the two tasks, but while completing the task, they would need to move items blocking those required for the task at hand (i.e., the seven irrelevant items were placed in the way) and a memory test was administered after completion of the task. The results indicated that irrelevant objects the participants moved in completing the task were more likely to be remembered than objects they did not interact with in the immediate environment. However, when asked to recall specific features of the objects in the kitchen such as color or shape, participants showed an increased memory for objects relevant to their given task as well as any object they manipulated. Not only has it been found that interacting with an object facilitates memory for that item, but interaction can also alter our spatial representations of those items (i.e., items we pick-up are grouped as physically closer together in memory; Thomas, Davoli, Brockmole, 2013). This lends itself to greater discussion of how interacting with our environments affects our representations of them, however far more research into this domain is needed.

In a new exploration of Maier's (1931) two-string problem, experimenters added a clever manipulation to examine potential embodied influence in overcoming functional fixedness (Thomas & Lleras, 2009). Recall in original task, participants are presented with two strings tied to the ceiling and are told to tie the string ends together. The problem therein is that the strings are long enough to be tied together, but short enough that the subject is unable to take a hold of one string and walk to the other string to tie them together. Around the room is a number of objects, including a pair of pliers that can be tied to a string, allowing the string to be swung to the opposing string and subsequently tied. In the new iteration of the task, Thomas and Lleras had their participants take breaks in between sessions of solving the problem, during which they were prompted to either swing their arms or engage in stretching. Unsurprisingly, the participants who swung their arms during the break were more likely to solve the problem than those that stretched during the break. The interpretation here, that participants' insight to solving the problem was implicitly primed by the movement of their arms, thus demonstrating an embodied action priming effect over their spatial reasoning.

Of the six views, the notion that cognition is for action might arguably be one of the stronger. Despite this, it might be apropos to consider how, if one accepts this view, it might change the general framework for how we characterize and perhaps research cognition.

Others around the time of Wilson's article argued that some of our traditional approaches to cognition were antiquated. Take for example memory, about which Glenberg (1997) notes that our traditional paradigm in characterizing memory is that it simply a storehouse of knowledge, but that it might be more apt to characterize it as a repository that codes potential means for interaction with the physical world (Glenberg, 1997). Researchers have echoed similar sentiments lately, for example Engel, Maye, Kurthen and König (2013) argued that cognitive science has taken a "pragmatic turn" toward examining cognition as being situated for "action," consistent with Wilson's fifth view, and assert that classical approaches within the field of cognition fail to adequately solve certain lines of questioning. Particularly, that when assessing cognitive function without considering how it is related to action, we end up with an incomplete theory of how the system works. The pragmatic term they propose, is to treat all theories of cognition as theories of action, or in the least, when assessing a cognitive domain, address how any singular system might potentially aid in the production of action.

An interesting aside in Engel et al.'s review is the discussion of representations and their role in the how we characterize cognition. While they do not propose that the notion be discarded, they assert that we should replace "representations" with a term that carries less "cognitivist burden," and lends itself more freely to the discussion of cognition being for action. They in turn propose the term "directive" be used in place of representation, a directive denoting any action-related role of patterned dynamic interactions (i.e., representations) arising within cognition. This is an interesting idea, and the topic of representations' place in recent cognitive science will be discussed in greater detail a bit later in this paper. Succinctly, Wilson's fifth view may still serve as a reasonable guiding principle for cognitive research, as we should generally consider how any cognitive system (and that systems underlying representations or directives) subserves action and general survival.

View 6: Offline cognition is body based

While examples have been given earlier in this paper as to how our bodies can aid cognitive processes in an active online manner (e.g., gesture to convey a point or offload memory, hand-altered vision, body orientation facilitating attention, etc.), a question still remains about the interaction between motor functions and offline, un-situated cognition. In basic form, the idea that offline cognition is body based can be as simple as using our fingers to aid in counting a mental list, but this can be a much subtler phenomenon as well, such as the engagement of motor areas in the brain when mentally simulating the action of a task. Many completely offline abstract activities utilize brain regions typically involved in motor action. Of the six views discussed by Wilson, this one has held up fairly well in light of the past decade and a half worth of research.

Prior to the Six Views review, Wilson (2001) made a strong case for the involvement of sensorimotor coding in working memory, that is, the notion that sensorimotor processes are happening in the background in order to aid the manipulation and representation of information stored in our working memory system, an idea that has been substantiated even further since 2001. In a task designed to examine the effects of motor affordances on recall in a visual-span task, researchers screened large sets of images of objects based on the object's "manipulability," that is, how easily an individual could use the item with their hands (Guérard & Lagacé, 2014). With these ratings a span task was completed in which the middle item of a set of seven objects to be remembered was varied as a function of its manipulability. So for example, a hammer might appear in the middle of a set of un-manipulatable items such as a tree, cloud, or statue. It was found that memory for the center items of these lists improved when the the manipulability of the object increased compared to the other items within the set. In a second experiment, the researchers had participants complete the same memory task, but this time engage in a secondary "motor-suppression" task while learning the set. This motor-suppression task required the individual to ball both of their hands into fists, and outstretch each of their fingers one at a time, repeating the processes once all ten fingers had been outstretched. Remarkably, when engaging in this secondary task, the enhanced memory performance for manipulatable objects disappeared. This provides further evidence that motor affordances of objects can enhance the memory for those items, and that the some of the underlying processes involved in interacting with them are activated when representing these objects. If motor suppression via simple hand fidgeting can reduce the salience of to-be-remembered items, then we might infer that offline cognition still requires the engagement of some motor systems, even if only for the representation of items or activities that contain motor affordances.

Recent evidence from numerical cognition lending itself to the notion that offline cognition is body based has been demonstrated in the types of eye movements that participants make when solving arithmetic problems (Hartmann, Mast, & Fischer, 2015). In a task designed to examine the effect of our numerical spatial biases on eye-movements, participants solved arithmetic problems while staring at a blank computer screen. The problems were presented aloud and consisted of both addition and subtraction. Participants' eye movements varied as a function of both problem type; gazes moved upward while solving addition, and downward while solving subtraction, and as a function of operand magnitude; with gaze position moving more to the right as operands became larger. While the impetus of this study was to examine the relationship between our mental number line and eye movements, another line of research might be pertinent here as well. Past research has examined the relationship between components of working memory and particular arithmetic processes (Caviola, Mammarela, Cornoldi, & Lucangeli, 2012). Particularly relevant here is that problems presented horizontally (e.g., left to right such as "13 x 7") have been found to be more reliant on the phonological loop than problems presented in a vertical manner (i.e., the operands placed above one another). While not addressed in Hartmann et al.'s work, it might be that these eye movements were indicative of these arithmetic problems being manipulated in working memory, resulting in gaze patterns indicative of the way our internal locus of attention moves through representational space. The internal offline representations of the problems in these instances are body based as demonstrated by the corresponding eye movements.

A recent review discusses the debate over whether concepts are embodied by default (Dove, 2015). Supporters of the notion argue that all concepts are essentially embodied and rooted in corresponding sensorimotor systems. Critics of this view cite research that points to "amodal" areas of the brain that often happen to be near-to but separate from sensorimotor areas (e.g., Chatterjee, 2010; Mahon, 2015; Mahon & Caramazza, 2008). A middle ground exists between both arguments that argues concepts are grounded in some respect upon action or perceptual systems (Binder & Desai, 2011). Dove addresses this current debate in the literature from three angles. First, he argues that there is a problem of "generalization" within the literature. Particularly, can we generalize embodied notions, such as Wilson's sixth view of the body based nature of cognition, to all examples within a domain? Citing numerous examples from research on semantic memory, Dove gives the example of how both higher order categorical examples have issues when arguing for a sensorimotor involvement in representation. For example, the category of MAMMAL is an example of types of animals, but at the bottom of the hierarchy you will find concrete animals that can be involved in some sort of simulation. Conversely, a notion like ODD NUMBER is abstract because it does not intrinsically have any concrete referents. So in this instance, Dove argues you may not be able to generalize the body-based notion of embodiment to all examples from semantic memory. Two, Dove argues embodiment theory has a problem of flexibility, wherein issues of embodiment are often assessed through an "embodied/disembodied dichotomy." Alternatively, he asserts that we need to be developing theories concerning the relative contributions of embodied representations to any line of inquiry. Third, is the very problem of disembodiment, and the fact that it is simply very challenging to examine how abstract representations (e.g., JUSTICE, TRUTH) can be grounded in sensorimotor systems. Some might argue that even the understanding of abstract concepts is rooted in concrete physical things (as noted in our discussion of metaphors in view 1), but abstract concepts do offer a theoretical hurdle for the argument that offline cognition is embodied. Researchers tackling this problem from a neurological perspective have found some regions apparently implicated in amodal processing of abstract concepts. Yet, while in many instances these areas show enhanced activation the more abstract a concept becomes, studies have not demonstrated that even abstract representations are fully amodal, existing completely independently from engagement of modal systems. Regardless of how you might interpret the evidence for amodal disembodied systems, Dove's points are compelling. The strongest takeaway is the notion that we need to asses the issue on a case by case basis; to what end is the phenomenon of interest embodied or disembodied, or to what end is the offline phenomenon of interest body based?

Neurological Evidence Integrating Cognitive and Motor Systems

Executive function, while its definitions can vary from researcher to researcher, is at the very least generally agreed upon to be a voluntary and controlled system of the individual. Some nuances between the underlying neural substrates of executive function do exist however. Particularly, the prefrontal cortex (PFC) underlies two types of executive function. The first, "metacognitive" executive function incudes skills like problem solving, planning, concept formation, strategizing, and implementation (Koziol, Budding, Chidekel, 2012), abilities typically requiring working memory and attention which fall under this umbrella of executive function. Alternatively, "emotional/motivational" executive function includes coordinating our cognition with affective components in order to meet the situational requirements necessary to fulfill biological needs. This type of executive function depends on the medial and orbitofrontal areas (Ardila, 2008). Despite these areas association with executive function, evidence suggests that depending on the amount of embodiment within a given task, differential amounts of neural resources are recruited from motor regions, which we be discussed in the following section.

One of the more overarching explanations for the mechanisms involved in embodiment is the notion of "sensorimotor simulation," which Dijkstra and Post (2015) cover in a recent review. There are several claims of this theory. The first and simplest is the idea that perception of a stimulus automatically triggers internal simulation of and/or reenactment of the stimulus. Human behavior is then facilitated when our actions are congruent to our mental simulation, and hindered when incongruent (as seen in many of the aforementioned behavioral tasks). Second, simulation can be impeded by a task that utilizes the same resources required for the action simulation (as also noted in many of the above tasks), similarly to what is found in the standard dual-task paradigms of cognitive psychology. Third is the claim that simulation may also work offline (much like Wilson's sixth view). Lastly is the claim that simulation depends on previous experience and skills. That is, an expert might show differential levels of simulation (and subsequent neural activation) compared to a non-expert. There are other claims put forth by embodied theorists, but the four listed here tend to form a concurrent thread across multiple lines of inquiry.

A recent model has been proposed to to explain how representations are grounded in motor systems (Martin, 2016). Grounding representations in action, perception, and emotion systems (GRAPES), outlines not just how conceptual information with physical features is grounded due to shared neural circuitry. While this model is not too dissimilar from previous notions of sensorimotor simulation, it does expand the idea a bit to encompass how even representations of our social world are grounded in simulation. Take the case of gesture, which is thought to emerge once premotor areas reach a threshold of activation and spread to activating motor areas. The idea here is that internal representations of an action or concept are triggering neural simulation, and subsequently the gestural action is produced (Alibali et al., 2014). In the case of conversation or speech, the listener, while benefitting in comprehension from the added gestural component, is also experiencing an added level of simulation through perception of the gesture. This process is thought to rely particularly on premotor areas F5 and inferior parietal areas (FabbriDestro & Rizzolati, 2008; Fogassi, Gallese, Fadiga, & Rizzolatti, 1998), areas considered to be the home of our mirror neurons. Other studies have implicated the supramarginal gyrus (SMG) and intraparietal sulcus (IPS) as playing a large role in the perception of gesture. One study found consistent SMG activation when participants viewed gestures conveying metaphoric or symbolic content in conjunction with the expected premotor areas (Skipper, Goldin-Meadow, Nusbaum, & Small, 2009). On the other hand (no pun intended), it may be possible that the IPS does not play a role in the interpretation of gesture, but rather the mere processing of another person's hand actions in space (Green et al., 2009; Willems, Ozyurek, & Hagoort; 2009).

Consistent with the previous accounts, the standard embodied theory of language is that comprehension involves the recruitment of neural resources congruent with the modalities of the words themselves, for example, motor regions are activated when hearing a replay of a physical activity and auditory regions become active when reading text about a particular song. The idea here is that language elicits a corresponding representation of the written or spoken language and to create this simulation of the language, there is recruitment of modality specific regions of the brain (Willems, Labruna, D'Esposito, Ivry, & Casasanto, 2011). Particular deficits in language comprehension have been found as a result of this interplay between other modalities and language, as individuals with Parkinson's disease have been found to show deficits in the comprehension of action verbs, but not for concrete nouns, and individuals with damage to right temporo-occipital areas show similar deficits but for visually priming nouns (Boulenger et al., 2008; Neininger & Pulvermuller, 2003).

FMRI studies have contributed greatly to the exploration of our mind body interplay. In one study, researchers attempted to isolate which brain regions were modally specific in text comprehension by having participants read while placed in an fMRI (Chow et al., 2014). For the narratives used in the task, there were three conditions; perception (e.g., simulating an environment like a theater or city), action (e.g., playing a piano, jogging, baking), or emotion (e.g., winning a prize, being robbed, receiving complements). The left inferior frontal gyrus (LIFG), left posterior middle temporal gyrus (pMTG), and bilateral anterior temporal lobes (aTL) were strongly activated across all stories, however there were several differences in the magnitude of connectivity between regions across story conditions. During the perception condition pMTG showed increased connectivity to the left parahippocampal gyrus, an area associated with the recognition of environmental scenes. LIFG showed similar differences in connectivity as a function of story components, with linkages to the right hippocampal gyrus as well in the perception condition, and greater connectivity in the action condition with the intraparietal sulcus. ATL activations was markedly different particularly during the emotion condition, with enhanced connectivity to the medial prefrontal cortex, posterior cingulate, and inferior parietal lobule. Much like the above study, other work has shown that reading about a character engaging in basic motor activities such as walking or grasping has been found to activate areas of posterior superior temporal sulcus along with ventral temporal areas, premotor cortex, and the left motor cortex (Deen & McCarthy, 2010; Saygin, McCullough, Alac, & Emmorey, 2010).

But what does this neuro-jargon heavy explanation of the findings mean for the cognitive psychologist? Specifically, that in our mental simulations, we recruit perceptual, motor and emotional knowledge from respective brain regions in order to create multi-modal representations of what we read. Chow et al., (2014) even go so far as to imply that these mechanisms functionally constitute the the neurological real estate involved in our construction of situation models (Zwaan & Radvansky, 1998). By inference, we could theorize that any mental simulation, even those elicited from autobiographical memory, draw upon the same underlying neurological substrates, demonstrating modality specific recruitment of resources. Recent neurological evidence supports this claim, as narratives containing action sequences elicit the same recruitment of modality specific resources (Niedenthal et al., 2005; Körner et al., 2015). Further, simulations need not even be explicitly of motor actions, as activation within the somatosensory cortex has been found for merely viewing images of objects that possess motor affordances (i.e., graspable tools; Smith & Goodale, 2015).

Similarly, looking at images of objects that create specific sounds (musical instruments or animals) activate the auditory cortex (Meyer et al., 2010). Further, the previous accounts noting engagement of modal systems for motor simulation make the standard notion of executive function relying only on the prefrontal cortex and orbitofrontal cortex a bit nebulous. A more discreet pattern of activation within these two areas seems dependent on the degree of abstraction one is engaging in, as simulations grounded in other modalities will recruit modal resources as needed.

Recent Trends and Discussion

Near the turn of the century a there was a debate between researchers regarding the existence of abstract symbolic representations within cognition (see Pylyshyn, 2000 for an early review), with some suggesting that cognition should minimize its reliance on representations in explaining how we understand our world (Clark, 1999; Slezak, 1999). Proponents of the anti-representational view approach the problem from multiple angles; some arguments are merely regurgitations of older behaviorist approaches with more complex mechanics, while others propose direct unmediated sensorimotor mechanisms for interacting with the world. Despite critics' best attempts in the past decade, there is still a great deal of evidence in support of the existence of representations, along with a recently renewed interest in substantiating their existence in many researchers (Binder, 2016; Martin, 2016; Gotts, 2016; Reilly, Peelle, Garcia, & Crutch, 2016).

Traditional theories about the nature of our cognition operate under the assumption that knowledge resides in modular systems, for example, knowledge about the world stored in semantic memory, personal experience via autobiographical memory, along with separate modules for areas such as perception, action, or emotion (Pylyshyn, 1984; Smith & Medin, 1981; Tulving, 1972). However, other lines of inquiry support the notion that these systems may be amodal, and may not rely on these separate substrates as much once thought (Barsalou, Simmons, Barbey and Wilson, 2003). Using the example of a visual scene such as a park; in a traditional amodal system, the visual input travels through sensory pathways, eventually forming a perceptual representation of this sensory input, which then is deconstructed further into a feature list (i.e., park bench, trees, grass), or causes spreading activation of objects in the scene via semantic networks (i.e., "squirrel Isa animal").

These amodal systems take reconstructions of a visual stream from representational space and break it down further into linguistically based conceptual knowledge. Modal approaches on the other hand are not dependent on these separate linguistic systems, but rather, have additional processing of these features, via modally specific memory systems based on the sensory input. These modal sensory representations can then later work together to reconstruct earlier sensory inputs into representations. Pezzulo (2011) proposes a compromise between the two seemingly disparate accounts of cognition requiring symbolic representation or alternatively a purely sensorimotor based system.

Pezzulo posits that we have "embodied representations" that are neither carbon sensorimotor copies of our environment nor strictly symbolic or linguistically based. These embodied representations, which contrary to amodal based conventional models, rely on modality-specific systems and their underlying neural substrates. Unlike purely sensorimotor based models, the embodied representations can then be internally re-enacted and manipulated, much like simulations or rehearsal within our conventional working memory models. These representations are not unique to humans, and reside in any organism that engages in planning or goal directed behavior.

Pezzulo outlines three tenets that his paradigm is based around. First is that an organism's knowledge and ability to form representations arises from "sensorimotor interaction." This essentially means that our representational ability came about from an environmental need to plan courses of of action for the future. For example, our ability to grasp a coffee cup on the table is encoded with the features such as weight and shape that allow us to interact with it. This representation of a coffee cup is not amodal, but rather, has the features specifically needed for our ability to interact with it. These representations for action can then be reused outside of their original context in more generalized procedural formats. Further, this mechanism can be used to simulate in offline scenarios the act of moving the cup (i.e., imagining lifting a coffee cup and taking a drink).

This mechanism is not simply bound to just procedural knowledge necessary for action planning, but can contribute to more abstract forms of knowledge leading us to Pezzulo's second tenet; that the mechanisms that anticipate environmental changes and allow for simulated action and subsequent execution of action not only produce procedural action but create declarative knowledge. For example, your sensorimotor experience with coffee cups informs your semantic knowledge about the cup, you know a cup might be warm to the touch, or that the liquid inside could burn your tongue without direct perception of these attributes. These characteristics arise without direct interaction or perception, and instead are reconstructed from declarative knowledge. With this second assertion, Pezzulo is essentially stating that the causal reason for feature lists (Medin & Schaffer, 1978) in our semantic storehouses of memory are the byproduct of environmental interaction, and that this ability to hold such knowledge came about as an evolutionary need to keep this knowledge available for survival. Lastly, these embodied representations allow internal manipulations that constitute executive function, or what Pezzulo refers to as "internalized situated action." Similar to Pezzulo's account, Binder (2016) proposes a further argument for the existence of abstract conceptual representations. Noting strong empirical evidence for modal sensorimotor systems involvement in conceptual representation (Fischer & Zwaan, 2008; Kiefer & Pulvermüller, 2012; Meteyard, Rodriguez Cuadrado, Bahrami, & Vigliocco, 2012), Binder notes converging lines of evidence for supramodal systems that integrate and form the neural substrates for representation across multiple modalities or within strictly abstract examples.

Recent critiques of embodiment come from detractors arguing that the basic notions of embodied theory offer nothing particularly new, and that the principles are often vague, using tired clichés about the optimization of survival or the interplay between perception and action (see Goldinger, Papesh, Barnhart, Hansen, & Hout, 2016 for one such critique). Sure, some of the assertions of embodied cognition might fall on flimsy ground when trying to assert some grand unified theory of embodiment, but the guiding principles are sound. Given the evidence discussed in this present review, it is clear that we need to cease lines of psychological inquiry that consider the mind in isolate, in the classic Cartesian dualistic manner. Alternatively, we should endeavor to conduct cognitive science (and in turn cognitive psychology) in a manner that considers not only the interplay between motor systems and more complex cognitive ones, but also considers the affordances of the body and the immediate environment in all lines of inquiry.

This is not to say that in studying more abstract phenomena (e.g., semantic memory or narrative comprehension) we need to consider the body as part of the cognitive system, but rather in experimental design researchers should consider the influence of action verbs or motor based simulation when considering their stimuli (much like we currently control for word frequency by using one of the many corpuses). More broadly, in conceptualizing the general framework of psychology, we may want to consider embodied phenomena with regard to their facilitation or priming of motor areas. Engel et al.'s (2013) "Where's the Action? The Pragmatic Turn in Cognitive Science" echoes this standpoint, in which they assert that cognition should not simply be explained as providing internal models of the world, but further should be conceptualized as subserving action by being grounded in sensorimotor based systems.

Given the inconsistencies within the existing body of embodied research, several of Wilson's views are now outmoded. Particularly, views (2) cognition is time pressured, (4) the environment is part of the cognitive system, and (6) offline cognition is body based, fail quickly when put to scrutiny in light of evidence. Having to assess these views on case by case basis in experimental design or real world scenarios essentially nullifies their potential guiding views. That being said, it is not necessary that we disregard them entirely. While not all cognition is time pressured, there are many scenarios where time sensitivity might be influenced by embodied phenomena that have not yet been examined (e.g., Could the attentional blink or rapid serial visual presentation performance be affected by some of the aforementioned attentional orienting effects of the body?). Regarding view 4, the environment is not intrinsically part of the cognitive system, but due to the ever increasing adoption of mobile technology and emerging tech trends like augmented reality, we may see increasing reevaluations of where the cognitive system ends and where the environment begins. Lastly, all offline cognition is clearly not body based, but the interplay between motor systems and offline cognition has not fully been elucidated to frame all offline cognition in a Cartesian manner.

While some of the six notions are not fully supported by the literature, the past decade and a half of new research lends itself to the following revision of Wilson's views that can serve as general guiding principles:

1. Cognition is reliant on situated systems

Because the current evidence tends to support some representational reliance on modal based systems that serve and evolved for situated action, higher order cognitions' dependence on them should be generally considered in research, even in non-situated scenarios. These systems were at one point, more time pressured than now, a consideration that may be necessary in some research scenarios but not all.

2. Environment and affordances influence cognition

We off-load cognitive work onto our environments, and while considering the environment to be an extended part of our cognition does not hold across all scenarios, it should be considered in experimental design. Additionally, the affordances of the environment, and the potential affordances of even symbolic information should be considered across lines of inquiry.

3. Cognition serves action

Not all cognition must be "for action," but generally all effortful and explicitly produced action is dependent on cognition (barring automaticity from practice and autonomic responses like the orienting reflex). As such, many offline forms of cognition can be body based, and most types of mental representation involve the recruitment of modal resources, even if the integration across systems is reliant on supramodal mechanisms.

The recent August 2016 special issue of the Psychonomic Bulletin & Review focused on "the representation of concepts," yet at first glance you might think the issue focused on embodiment, as over half of the articles focused particularly on the ways in which representations recruit body based motor systems in their creation. In an introduction to the issue Barsalou (2016) notes that across the articles, one key element is "neural reuse," that is, the cross-modal functions of many neurological structures serve both physical action and representational simulation. Further, he argues that any form of conceptual processing requires "flexible context-dependent" representations, the context dependence being either environmental or bound to sensory modalities. While some disagreement still exists within the literature about the extent to which all cognition is embodied, there surely is enough evidence to adopt Barsalou's notions (and perhaps the three updated views proposed above) as underlying principles in our approach to cognitive science. The evidence supporting the integration of modal systems into basic concept representation (and even more symbolic forms) is robust enough that a reassessment of the traditional more modular approaches to cognition should be considered.

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