RESEARCH ARTICLE

Embodied Cognition and Human-Machine Coexistence

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ABSTRACT

Recently, we discussed the relative importance of direct perception, embodiment, metaphors, and ethics for cooperative human-machine coexistence. The present paper deepens the examination of embodiment and direct perception by considering differences between computational and representational models on one hand and embodied cognition on the other. We found that to achieve true artificial intelligence (AI) and, hence, a cooperative human-machine coexistence, research must overcome the limitations of computational and representational models. This can be reached by connecting machines to the world through bodies that exhibit sensory and motor skills as demonstrated by embodied cognition. Furthermore, substantial improvement in AI could be achieved by adopting a hybrid framework in which embodied cognition, for example, may contain representational, abstract, and symbolic aspects. The adoption of such a "both and" instead of "either or" view is a more realistic approach for progress in AI applications.

Keywords: Artificial Intelligence, Embodied Cognition, Human Intelligence, Human-machine Coexistence, Phenomenology

1. INTRODUCTION

The field of soft computing comprises three branches of research and applications: (1) Neural networks that serve as a framework for modeling how brains function, (2) fuzzy systems that model how humans describe the world around them linguistically, and (3) evolutionary computation that accounts for variation and natural selection in the biological world (Keller et al., 2016). Current research in soft computing exploits the tolerance for uncertainty, ambiguity, approximate reasoning, and partial truth to achieve tractable, robust, and computationally economic solutions. As previously explored (Hamid et al., 2017), one issue in the application of soft computing is the degree to which human intelligence and artificial intelligence (AI) share similar quantitative or qualitative properties or both. Despite the clear differences between AI on one hand, and the first-person perspective of lived experience of humans on the other, human-machine coexistence is increasing (Hamid et al., 2017).

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In a recent work, we discussed the relative importance of direct perception, embodiment, metaphors, and ethics for cooperative human-machine coexistence (Smith and Hamid, 2017). The current work examines models of embodied cognitive science with an emphasis on the significance of physical existence and perception in order for AI to capture successfully the dynamics of the interactions of the brain, body, and world. The paper is organized as follows: Section 2 addresses phenomenology as a framework for describing first-person experiences along with Gibson's (2014) account of information in textured grounds as the source of direct perception (as opposed to information processing models in which the processing of visual stimuli, for instance, after it enters the eye becomes the source of perception). In Section 3, we introduce Merleau-Ponty's view of embodied existence in the world as primary in the process of perception.

We then discuss in Section 4 the integration of the body in cognitive science and consider its implication in the design of interactive artificial systems. We finally conclude in Section 5.

2. Gibson's Direct Perception

Phenomenology has typically used a figure-ground structure to explain experience in general and perception in particular, applying the methodology to a number of areas of interest (Smith, 2002). Rubin's vase in is probably the most common example of a figure-ground grouping [Figure 1a]. Whenever one's lived experience matters and nuances of first-person human experience are important – in contrast to third-person behavioral observations, measurements of the body, or any other single, privileged position – empirical phenomenology provides a proper methodology to follow (Pollio et al., 1997). Although it does not use interviews to look for themes as does the methodology above, Gibson's (2014) direct perception is one approach that has impacted the field of ergonomics by focusing on grounds in the process of perception. His ecological view claims ground in the environment defines the spatial character of the visual world, not what happens to stimuli after entering the eye. In short, information in a textured ground, not objects, explains perception. Gibson became interested in the world as a source of information instead of looking for processing mechanisms in one's head, and he subsequently contradicted the centuries-old epistemology of perception as the processing of copies. Gibson states, we perceive space directly from the ground, which explains the term direct perception.

A ground in many cases is a continuous surface or an array of adjoining surfaces. Gibson provided examples of optic arrays and looked for patterns of optic flow in them such as the experience of changes in the flow when approaching or moving away from a certain point [Figure 1b]. Moreover, learning does not merely come from the stimulus-response model of behaviorism. All spatial perceptions are in regard to a textured ground, usually the earth (Gibson, 2014). The spatial character of the visual world is given not by an analysis of the objects in it but rather by a consideration of the background against which the objects appear and become figural. In addition, most perceivers are in motion either because they are moving in some direction or they are moving their heads. Some information, however, remains constant as an observer moves. Gibson referred to a non-change as an invariant, defined as a property of the environment that remains constant despite illumination changes or movement of the observer (Gibson, 2014).

In stark contrast to what Gibson refers to as cognitivism, in direct perception, no intervening mental processes are necessary. He simply rejects any so-called operations of the mind, mental entities such as sense data. Grounds provide the information necessary for us to perceive directly, and we use such information immediately with no need to transform it. Again, unlike Gibson's (2014) characterization of the old idea that we process sensory inputs and convert them into perceptions – the information processing model in any of its various forms – his claim is the extraction of invariants from the stimulus flux is a more accurate model of visual perception. As shown in Figure 1c, an observer's movement toward a location results in environmental textures that flow everywhere except the invariant center. To stay on course, one needs to keep the center of the optical flow pattern on the destination. Importantly, when Gibson referred to representational models as old, he was correct in that the idea goes back to Democritus (460–370 B.C.). In addition, primarily due to Plato (approximately 428–348 B.C.), the representational theory has been particularly influential (Malone, 2009).

One application of Gibson's model involved pilots landing aircraft in the earlier days of aviation. In some cases, airplanes were not stopping soon enough on runways. Gibson determined that the relatively fast or slow flow of the optic array in relation to a fixed point of reference gave the sensation of speed and apparent speed related to one's distance from the ground. As a consequence, Gibson was able to explain how pilots in a cockpit high enough from the runway sensed they were moving slow enough to stop before a runway ended, when in fact they were running out of space on the runway to stop.

Although typically presented in contrast to information processing and Gestalt psychology, Gibson's model of perception is not entirely passive. The role of a moving, embodied active observer is clear throughout his research, and in his analysis of active touch, there is a distinction between active and passive perception. For example, an observer may actively explore the surfaces of objects and not merely feel an experimenter pushing on one's skin. Bottom-up models of perception where no learning is required, such as that of Gibson, are not applicable to all situations in the same way that any top-down model is also not uniformly appropriate, but Gibson's work clearly demonstrates the usefulness of direct perception.

3. MERLEAU-PONTY'S VIEW OF EMBODIMENT

Merleau-Ponty is the best theorist to address our embodied existence in the world as primary in the process of perception, and the significance of the body-as-subject.

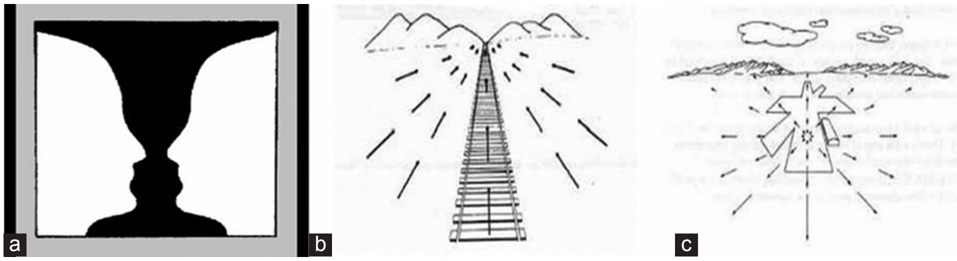

Figure 1. (a) Rubin's figure. (b) The pattern of optic flow when looking out of the back of a train. (c) The point toward which a pilot is moving appears motionless, whereas the rest of the visual environment appears to move away from that point. The figures were retrieved from (a) http://figuresambigues.free.fr, (b and c) https://frederikkechristiansenpsychology.wordpress.com

According to the main idea of Merleau-Ponty, our embodied inheritance is more fundamental than our reflexive capacity, and our analytic mode is derivative from the body's immediate exposure to the world (Merleau-Ponty, 1962). A first-person perspective reveals the failings of both empiricism and what he calls intellectualism, also known as philosophical rationalism or idealism. Stated simply, we have a world and access to the world through the body. When Merleau-Ponty states, we are our bodies, he does not undermine so-called mental phenomena, but rather he incorporates the perceiving mind into an incarnated body. Using our minds is inseparable from how we are situated physically. In other words, in an embodied state of being, the material and ideational are intimately linked in the body-subject that thinks and perceives. Merleau-Ponty stresses the body is not solely an object, merely one of many material components of the world, but is our means of communication with the world (Internet Encyclopedia of Philosophy, 2017).

One example, he provides is when one's left-hand touches the right hand while the right-hand touches an object; the right hand as object (muscles, flesh) is different from it as a touching subject (Merleau-Ponty, 1962). This is how one's body is both perceived object and perceiving subject, if not simultaneously then in an oscillation. Another example is when both hands are pressed together, as either hand can alternate in its role of either touching or being touched [Figure 2]. It is not the case that one simply has two sensations together as if grasping two objects lying next to each another. The ambiguity of touching and touched is representative of the full process of perception, and when the body-subject acts, it is inseparable from when the body-subject perceives. Merleau-Ponty also refers to the reversibility of the body in its ability to be both sentient and sensible (Merleau-Ponty, 1962). Furthermore, consciousness is better understood as a matter of "I can" instead of "I think that." In short, our lived experience denies the differentiation of mind from body and does not allow the detachment of subject from object (Internet Encyclopedia of Philosophy, 2017).

Figure 2. The ambiguity of touching and being touched: Body as subject and body as object simultaneously. Picture retrieved from: https://www.123rf.com.

4. INTEGRATION OF THE BODY IN COGNITIVE SCIENCE

Embodied cognitive science is in contrast to the formerly dominant view of the body as peripheral to cognition and that any computations cannot occur without mental representations. According to computational or representational views, cognition happens when a device in a system - typically human but machine-based in the case of AI - uses, supports, or otherwise manipulates symbols for goal-directed behavior (Cohen and Murphy, 1984). The problem with view is that it does not allow for the full complexity of mental functions. Consequently, research in AI became stuck because it failed to imitate higher mental activities. Characteristics of embodied cognition, in contrast, depend on and are integrated with a body such that without a body there would be limited or even no corresponding thinking (Wilson and Golonka, 2013). Bodies considerably influence cognitive processing and serve as grounds for language and cognition. Stated differently, the body's position, multimodal sensory inputs, intuitions of the motor system, environmental interaction, and other aspects all shape features of cognition. Interestingly, cognitive scientists have six distinguished views about what embodied cognition is Wilson (2002).

One proposal of an embodied mind that attempted to integrate cognitive science and human experience (Varela et al., 2017) stated that sensorimotor capacities are embedded in biological, psychological, and cultural contexts. The authors used the word enaction to refer to the process of mutual interactions among physiology, sensorimotor circuits, and the environment and how these determine the experienced world. In this view, there is a clear connection of the brain, body, and world. It follows that only organisms with certain characteristics, namely, certain skills or organs such as hands or eyes, would be able to have particular cognitive capacities. One of these authors, Francisco Valera, is also known for popularizing neurophenomenology and began to support embodied philosophy in 1990s. Although the work of this group included Buddhism and psychoanalysis, as well, these topics are not as relevant to the current discussion.

According to embodied cognition, there are three ways cognition depends on the body. The body can serve as a constraint on cognition, a distributor for cognition, or as a regulator of cognitive activity (Venon, 2014). The body acts to condition cognition by playing one of these three roles. Any kind of variation in bodies is an example of a constraint on cognition when it constrains the content of representations. Some kinds of thought will simply be easier than others depending on the body in question. The body also distributes, or shares in the processing of, load between the brain and the body. An organism's body regulates cognitive activity to coordinate action and cognition. Thus, the body is fundamentally important in the control of cognition and does not merely aid in the transmission of sensory input.

Similarly, robotics researcher Brooks (1990) argued that we will be able to achieve true AI only with machines that have sensory and motor skills and are connected to the world through a body. His emphasis is on intelligence without symbolic representation and ongoing interaction with the world, not just internal algorithms. Abstract manipulation of symbols in AI failed, for the most part, to become grounded in physical reality. Hence, an embodied methodology started to gain momentum.

Brooks (1990) also stated that reliance on a model of representation disappears when intelligence is approached in an incremental manner, or when there is strict reliance on interfacing to the real world through perception and action. Furthermore, it is unnecessary to decompose an intelligent system into independent information processing units that need to interface with one other through representations. Rather, the intelligent system, he designed decomposes into independent and parallel activity producers that interface directly to the world through perception and action. There are no longer central and peripheral systems because everything is both central and peripheral. To demonstrate the concept, Brooks built a series of mobile robots able to operate unsupervised based on the above principles, referring to them as creatures in standard office environments. There were four requirements for these creatures: They must (i) be able to maintain multiple goals, (ii) cope with environmental changes both appropriately and timely, (iii) be robust in interaction with the dynamic environment, and (iv) even be able to "do something" in the world, or have some purpose in being (Brooks, 1990. p. 143).

Likewise, the idea that minds are for doing, not thinking, is the product of Andy Clark's book being there: Putting brain, body, and world together again (1998). Rather than becoming a walking encyclopedia, a more successful aim for an AI would be to understand the dynamics among the brain, body, and world. Synthesizing techniques from neuroscience, robotics, and infant psychology, Clark examined many adaptive behaviors and suggested that the key to understanding the brain is to see it in terms of embodied activity. To treat cognition solely in terms of problem-solving is to depart from the world in which our brains evolved to guide us.

The work of Lakoff and Johnson (2003) in linguistics also supports the prevalence of embodiment, specifically the experiential grounding, coherence, and systematicity of metaphorical concepts and their role in how we fundamentally understand, organize, and share the world. The idea relevant for this paper is that metaphors are primary not only for language but also in human thought processes. They dominate cognition because our conceptual system is structured metaphorically, and this is why metaphors as linguistic expressions are possible and sensible. The authors also demonstrate how an experiential view can explain how metaphors are frequent, organized, and useful, in contrast to any view that neglects the necessity of an experiential basis. Metaphors structure personally meaningful concepts such as "education is a journey," "time is money," "life is a play," "argument is war," and "knowledge is food." Explanations of particular metaphors ("social organizations are plants"), however, are not set in stone. To understand metaphors fully, we cannot separate them from their experiential base that is often grounded in the body through physiological development. More generally, basic orientation metaphors such "in vs. out" and "up vs. down" reveal a fundamental understanding that is based on the body. It follows that rational corresponds to up and emotional to down (Lakoff and Johnson, 2003).

5. CONCLUSION

Whether the limitations of computational and representational models of cognition to effect progress in AI were recognized 25 years ago or only more recently (Dreyfus, 1992), it is no longer necessary to adopt a single framework for substantial improvement. Embodied cognitive science is one promising approach, and there will be other applications that allow us to acknowledge problems and implement innovative solutions for acute societal problems such as combating money laundering (Hamid, 2017) or promoting green technologies for smart cities (Schaffers et al., 2011). The adoption of a "both and" view instead of an "either or" one as a guiding principle for research means that embodied cognition may contain representational, abstract, and symbolic aspects. Specifically, for AI, a major challenge is that in addition to having nobody, it does not participate in physical, linguistic, or sensorimotor development. Whereas such profound contrasts may render the unification of AI and HI insurmountable, the potential for human-machine coordination and coexistence remains strong (Smith and Hamid, 2017). What is needed is a more detailed understanding of the mechanisms at work in various subfields where AI and HI intersect and interact. Put simply, whereas computational and representational models require an intermediate entity that processes information so as to facilitate perception (which is a key element in the design of functioning AI systems), embodied cognition does not have this as a necessary condition. Given that the main goal of AI is for machines to reach the point where they can think like and interact with humans, we cannot ignore certain practical implications. Specifically, for AI engineers and cyber-physical systems' scientists, integrating the principles of embodied cognition into the traditional computational and representational models can widen the possibilities of designing better functioning (and probably more human-like) AI systems, which will increase cooperative human-machine coexistence.

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