

On the Role of AI in the Ongoing Paradigm Shift within the Cognitive Sciences

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Abstract

This paper supports the view that the ongoing shift from orthodox to embodied-embedded cognitive science has been significantly influenced by the experimental results generated by AI research. Recently, there has also been a noticeable shift toward enactivism, a paradigm which radicalizes the embodied-embedded approach by placing autonomous agency and lived subjectivity at the heart of cognitive science.

1. Introduction

Over the last two decades the field of artificial intelligence (AI) has undergone some significant developments (Anderson 2003). Good old-fashioned AI (GOF AI) has faced considerable problems whenever it attempts to extend its domain beyond simplified “toy worlds” in order to address context-sensitive real-world problems in a robust and flexible manner¹. These difficulties motivated the Brooksonian revolution toward an embodied and situated robotics in the early 1990s (Brooks 1991). Since then this approach has been further developed (e.g. Pfeifer & Scheier 1999; Pfeifer 1996; Brooks 1997), and has also significantly influenced the emergence of a variety of other successful methodologies, such as the dynamical approach (e.g. Beer 1995), nner

2.1 Theories of cognition

The paradigm that came into existence with the birth of AI, and which was essentially identified with cognitive science itself for the ensuing three decades and which still represents the mainstream today, is known as *cognitivism* (e.g. Fodor 1975). The cognitivist claim, that cognition is a form of computation (i.e. information processing through the manipulation of symbolic representations), is famously articulated in the Physical-Symbol System Hypothesis which holds that such a system “has the necessary and sufficient means for general intelligent action” (Newell & Simon 1976). From the cognitivist perspective cognition is essentially centrally controlled, disembodied, and decontextualized reasoning and planning as epitomized by abstract problem solving. Accordingly, the mind is conceptualized as a digital computer and cognition is viewed as fundamentally distinct from the embodied action of an autonomous agent that is situated within the continuous dynamics of its environment.

The cognitivist orthodoxy remained unchallenged until *connectionism* arose in the early 1980s (e.g. McClelland, Rumelhart *et al.* 1986). The connectionist alternative views cognition as the emergence of global states in a network of simple components, and promises to address two shortcomings of cognitivism, namely by 1) increasing efficiency through parallel processing, and 2) achieving greater robustness through distributed operations. Moreover, because it makes use of artificial neural networks as a metaphor for the mind, its theories of cognition are often more biologically plausible. Nevertheless, connectionism still retains many cognitivist commitments. In particular, it maintains the idea that cognition is essentially a form of information processing in the head which converts a set of inputs into an appropriate set of outputs in order to solve a given problem. In other words, “connectionism’s disagreement with cognitivism was over the nature of computation and representation (symbolic for cognitivists, subsymbolic for connectionsists)” (Thompson 2007, p. 10), rather than over computationalism as such (see also Wheeler 2005, p. 75). Accordingly, most of connectionism can be regarded as constituting a part of orthodox cognitive science.

Since the early 1990s this computationalist orthodoxy has begun to be challenged by the emergence of *embodied-embedded* cognitive science (e.g. Varela, Thompson & Rosch 1991; Clark 1997; Wheeler 2005), a paradigm which claims that an agent’s embodiment is constitutive of its perceiving, knowing and doing (e.g. Gallagher 2005; Noë 2004; Thompson & Varela 2001). Furthermore, the computational hypothesis has given way to the dynamical hypothesis that cognitive agents are best understood as dynamical systems (van Gelder 1998). Thus, while the embodied-embedded paradigm has retained the connectionist focus on self-organizing dynamic systems, it further holds that cognition is a situated activity which spans a systemic totality consisting of an agent’s brain, body, and world (e.g. Beer 2000). In order to assess the importance of AI for this ongoing shift toward embodied-embedded cognitive science, it is helpful to first consider the potential impact of theoretical argument alone.

2.2 A philosophical stalemate

The theoretical premises of orthodox and embodied-embedded cognitive science can generally be seen as Cartesian and Heideggerian in character, respectively (e.g. Wheeler 2005; Dreyfus 2007; Anderson 2003). The traditional Cartesian philosophy accepts the assumption that any kind of being can be reduced to a combination of

more basic atomic elements which are themselves irreducible. On this view cognition is seen as a general-purpose reasoning process by which a relevant representation of the world is assembled through the appropriate manipulation and transformation of basic mental states (Wheeler 2005, p. 38). Orthodox cognitive science adopts a similar kind of reductionism in that it assumes that symbolic/subsymbolic structures are the basic representational elements which ground all mental states⁴, and that cognition is essentially treated as the appropriate computation of such representations. What are the arguments against such a position?

The Heideggerian critique starts from the phenomenological claim that the world is first and foremost experienced as a significant whole and that cognition is grounded in the skilful disposition to respond flexibly and appropriately as demanded by contextual circumstances. Dreyfus (1991, p. 117) has argued that such a position questions the validity of the Cartesian approach in two fundamental ways. First, the claim of *holism* entails that the isolation of a specific part or element of our experience as an atomic entity appears as secondary because it already presupposes a background of significance as the context from which to make the isolation. From this point of view a reductionist attempt at reconstructing a meaningful whole by combining isolated parts appears nonsensical since the required atomic elements were created by stripping away exactly that contextual significance in the first place. As Dreyfus (1991, p. 118) puts it: “Facts and rules are, by themselves, meaningless. To capture what Heidegger calls significance or involvement, they must be *assigned relevance*. But the predicates that must be added to define relevance are just more meaningless facts”. From the Heideggerian perspective it therefore appears that the Cartesian position is faced with a problem of infinite regress. Second, if we accept the claim of *skills*, namely that cognition is essentially grounded in a kind of skilful know-how or context-sensitive coping, then the orthodox aim of reducing such behaviour into a formal set of input/output mappings which specify the manipulation and transformation of basic mental states appears to be hopelessly misguided

2.3 An empirical resolution

It has often been proposed that this theoretical stalemate has to be resolved in the empirical domain of the cognitive sciences (e.g. Dreyfus & Dreyfus 1988; Clark 1997, p. 169; Wheeler 2005, p. 187). The authors of the Physical-Symbol System Hypothesis (Newell & Simon 1976) and the Dynamical Hypothesis (van Gelder 1998) are also in agreement that only sustained empirical research can determine whether their respective hypotheses are viable. Research in AI⁵ is thereby awarded the rather privileged position of being able to help resolve theoretical disputes which have plagued the Western philosophical tradition for decades if not centuries. This reciprocal relationship between AI and theory has been captured with the slogan “understanding by building” (e.g. Pfeifer 1996; Pfeifer & Scheier 1999, p. 299).

In what way has AI research managed to fulfil this role? Dreyfus (1991, p. 119), for example, has argued that the Heideggerian philosophy of cognition has been vindicated because GOFAI faces significant difficulties whenever it attempts to apply its Cartesian principles to real-world situations which require robust, flexible, and context-sensitive behavior. In addition, he demonstrates that the Heideggerian arguments from holism and skills can provide powerful explanations of why this kind of AI has to wrestle with the frame and commonsense knowledge problems. In a similar vein, Wheeler (2005, p. 188) argues compellingly that the growing success of embodied-embedded AI provides important experimental support for the shift toward a Heideggerian position in cognitive science. He argues that Heidegger’s claim that a cognitive agent is best understood from the perspective of “being-in-the-world” is put to the test by embodied-embedded AI experiments which investigate cognition as a dynamical process which emerges out of a brain-body-world systemic whole.

2.4 The failure of embodied-embedded AI?

In light of these developments it seems fair to say that AI can have a significant impact on the ongoing shift from orthodox toward embodied-embedded cognitive science. However, while embodied-embedded AI has managed to overcome some of the significant challenges faced by traditional GOFAI, it has also started to encounter some of its own limitations. Considering the seemingly insurmountable challenge to make the artificial agents of current embodied-embedded AI behave in a more robust, flexible, and generally more life-like manner, particularly in the way that more complex living organisms do, Brooks (1997) was led to entertain the following sceptical reflections: “Perhaps we have all missed some organizing principle of biological systems, or some general truth about them. Perhaps there is a way of looking at biological systems which will illuminate an inherent necessity in some aspect of the interactions of their parts that is completely missing from our artificial systems. [...] I am suggesting that perhaps at this point we simply do not *get it*, and that there is some fundamental change necessary in our thinking” (Brooks 1997). Has the field of AI managed to find the missing “juice” of life in the past decade?

⁵ It is worth noting that there are compelling arguments for claiming that the results generated by AI research are not “empirical” in the same way as those of the natural sciences, and that this is likely to weaken their impact outside the field. Nevertheless, it is still the case that AI can provide “valuable tools for re-organising and probing the internal consistency of a theoretical position” (Di Paolo, Noble & Bullock 2000).

Hans Jonas (1966), it is claimed that such an autonomous system, one whose being is its own doing, should be conceived of as an individual in its own right, and that this process of self-constitution brings forth, in the same stroke, what is other, namely its world (e.g. Thompson 2007, p. 153). In other words, it is proposed that the continuous reciprocal process, which constitutes the autonomous system as a distinguishable individual, also furnishes it with an intrinsically meaningful perspective on its environment, i.e. autonomy lies at the basis of *sense-making* (Weber & Varela 2002).

It follows from these considerations that today's AI systems are not autonomous in the enactive sense. They do not constitute their own identity, and the only "identity" which they can be said to possess is projected onto them by the observing researcher (Ziemke 2007). The popular methodology of evolutionary robotics, for example, presupposes that an "individual" is already defined by the experimenter as the basis for selection by the evolutionary algorithm, and in the dynamical approach to AI it is up to the investigator to distinguish which subpart of the systemic whole actually constitutes the "agent" (Beer 1995). The enactive notion of autonomous agency therefore poses a significant difficulty for current AI methodologies. Nevertheless, it is worth noting that AI researchers do not have to synthesize actual living beings in order for their work to provide some relevant insights into the dimension of bodily self-regulation. Following Di Paolo (2003), a first step would be to investigate artificial systems with some self-sustaining dynamic structures. In this manner embodied-embedded AI can move beyond its current focus on closed sensorimotor feedback loops by implementing systems which have a reciprocal link between internal organization and external behaviour. Indeed, there are signs that a shift toward more concern with bodily self-regulation is starting to develop. This is demonstrated by an increasing interest in homeostasis as a regulatory mechanism for investigating, for example, sensory inversion (e.g. Di Paolo 2003), the emergence of sensorimotor coupling (e.g. Ikegami & Suzuki forthcoming), behavioural preference (e.g. Iizuka & Di Paolo forthcoming), and active perception (e.g. Harvey 2004).

3.2 Sensorimotor coupling and intersubjective interaction

Since sensorimotor embodiment is the research target of most current embodied-embedded AI, its results can have an impact on this aspect of enactivism. However, since the vast majority of such work is not concerned with how the constraints of constitutive autonomy are related to the emergence of sensorimotor behavior, it is not contributing to the enactive account of how an autonomous agent is able to bring forth its own cognitive domain. To become more relevant in this respect, the field needs to adapt its methodologies so as to deal with the enactive proposal that an agent's sense-making is grounded in the active regulation of ongoing sensorimotor coupling in relation to the viability of a precarious, dynamically self-sustaining identity (Weber & Varela 2002). This is an area which has been practically unexplored, although some promising work has begun (e.g. Ikegami & Suzuki forthcoming; Di Paolo 2003).

These considerations can be extended to the domain of intersubjective interaction, since this dimension of embodiment also involves distinctive forms of sensorimotor coupling (Thompson & Varela 2001). An enactive account of social understanding based on this continuity has recently been outlined by Di Paolo, Rohde and De Jaegher (2007). They make the important suggestion that the traditional focus on the embodiment of individual interactors needs to be complemented by an investigation

of the interaction process that takes place between them. This shift in focus enables them to extend the enactive notion of sense-making into the realm of social cognition in the form of *participatory sense-making*. The development of such an account is important for embodied-embedded AI, because most of its current research remains limited to “lower-level” cognition. Exploring the domain of social interaction might provide it with the necessary means to tackle the problem of scalability (Clark 1997, p. 101), in particular because such inter-action can constitute new ways of sense-making that are not available to the individual alone. The challenge is to implement AI systems that constitute the social domain by means of an interaction process that is essentially embodied and situated, as opposed to the traditional means of formalized transmissions of abstract information over pre-specified communication channels. Di Paolo, Rohde and De Jaegher (2007) review some initial work in this direction which demonstrates that “these models have the possibility to capture the rich dynamics of reciprocity that are left outside of traditional individualistic approaches”.

3.3 A fully enactive AI?

It is debatable if AI research should be considered as enactive rather than embodied-embedded if it does not address some form of bodily self-regulation⁶. In this sense the authors of *The Embodied Mind* perhaps got slightly carried away when they referred to the emergence of Brooks’s behaviour-based robotics as a “fully enactive approach to AI” (Varela, Thompson & Rosch 1991, p. 212). However, this is not to say that embodied-embedded AI does not have an impact on the shift toward enactivism, it does, but only to the extent that there is an overlap between the two paradigms. Its current influence is therefore by no means as significant as it has been on the shift toward embodied-embedded cognitive science. For example, Thompson’s recent book *Mind in Life*, which can be considered as a successor to *The Embodied Mind*, does not even include AI as one of the cognitive science disciplines from which it draws its insights (Thompson 2007, p. 24). Indeed, at the moment it seems more likely that the influence will run more strongly from enactive cognitive science to AI instead. Its account of *autonomous agency*, for example, has the potential to provide embodied-embedded AI with exactly the kind of bodily organizational principle that has been identified as missing by Brooks (1997).

its current preoccupation with sensorimotor interaction in the behavioural domain to include a concern of the constitutive processes that give rise to that domain in living systems. Maybe Brooks (1997) was right when he

noise and data⁸

his claims? If his analysis of the holistic structure of our “being-in-the-world” is one of the most influential accounts of the Husserlian phenomenological tradition, then why did it not succeed in convincing mainstream cognitive scientists? The regrettable answer is that, while his claims have sometimes been probed in the philosophical or empirical domain, there have not been many sustained and principled efforts in orthodox cognitive science to verify their validity in the phenomenological domain.

If enactivism is to avoid this fate then it needs to focus less on the development of enactive AI, and more on the promotion of principled phenomenological studies. Indeed, according to Di Paolo, Rohde and De Jaegher (2007) the central importance of experience is perhaps the most revolutionary implication of enactivism since “phenomenologically informed science goes beyond black marks on paper or experimental procedures for measuring data, and dives straight into the realm of personal experience” such that, for example, “no amount of rational argument will convince a reader of Jonas’s claim that, as an embodied organism, he is concerned with his own existence if the reader cannot see this for himself”. Thus, enactivism implicates an element of personal practice. Similarly, Varela and Shear (1999) outline the beginnings of a project “where neither experience nor external mechanism have the final word”, but rather stand to each other in a relationship of mutual constraints. They point out that the collection of phenomenological data requires a disciplined training in the skilful exploration of lived experience. Such an endeavour might already be worthwhile in itself, but in the context of the stalemate in the cognitive sciences it comes with an added benefit. In a nutshell this is because, while it is still the case that phenomenological data first has to be interpreted from a particular point of view before it can be integrated into a conceptual framework, generating such data also requires a change in our mode of experiencing. Moreover, this change in our experiential attitude is constituted by a change in our mode of *being*, and this in turn entails a change in our *understanding* (Varela 1976). Thus, it is this being, our everyday “Dasein”, which determines how we interpret our world. Of course, since we are autonomous agents this does not mean that actively practicing phenomenology necessarily commits us to enactivism. But perhaps by changing our awareness in this manner we will be able to understand more fully the reasons, other than theory and empirical data, which are at the root of why we prefer one paradigm over another.

5. Conclusion

The field of AI has had a significant impact on the ongoing shift from orthodox toward embodied-embedded cognitive science mainly because it has made it possible for philosophical disputes to be addressed in an experimental manner. Conversely, enactivism can have a strong influence on AI because of its biologically grounded account of autonomous agency and sense-making. The development of such enactive AI, while challenging to current methodologies, has the potential to address some of the problems currently in the way of significant progress in embodied-embedded AI. However, if an alternative paradigm is to be successful in actually displacing the orthodox mainstream, then it is unlikely that theoretical arguments and empirical evidence alone are sufficient. For this to happen it will be necessary that a *phenomenological pragmatics* is established as part of the general methodological toolbox of contemporary cognitive science. This shift of focus from AI to phenomenology coincides with a shift from embodied-embedded cognitive science to

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