The Extended Mind: A Dynamical Systems Perspective

Andy Forceno

 andy.forceno@uconn.eduAbstract

 Clark and Chalmers (2002) advance two hypotheses that both cognition and the mind extend into the environment. Both hypotheses are grounded in active externalism about mental content and the Parity Principle. Active externalism proposes that the external features of the environment in the present directly influence our mental contents and behavior. The Parity Principle states that a process or state in the environment is cognitive if it is functionally equivalent to a comparable intracranial cognitive process. This paper reviews two of the strongest replies to the hypotheses, namely that arguments for them commit the coupling-constitution fallacy and that the hypothesis of extended cognition is incompatible with any satisfactory criteria that distinguishes between cognitive and non-cognitive processes. This paper argues that a dynamical systems approach avoids both objections and offers a conceptual and methodological framework for an extended cognitive science. Lastly, an account of collective intentionality will be considered to show how groups of individuals can be the bearers of mental states.

1. Extending Cognition

 Clark’s and Chalmers’ argument for the hypothesis of extended cognition (HEC) rests on three thought scenarios about human problem solving. In the first example, a person sits in front of a computer that displays two dimensional geometric shapes and is asked whether they fit into sockets. To answer the questions the person must mentally rotate the objects. The second example is identical, except that the person can choose to have the computer rotate the objects for them rather than performing the rotation mentally. This is precisely how the video game Tetris works, in which players must fit two-dimensional shapes together by pressing a button to rotate them on-screen. In the final scenario, a person in the future sits in front of a computer performing the same rotation task, except that they have neural implants that allow them to mentally rotate objects as quickly as the computer in example two (Clark and Chalmers 643-44).

 All three scenarios are identical, except in terms of where the mental rotation operations are performed. In one and three, mental rotation is restricted to the skull, whereas the person in scenario two can delegate mental rotation operations to the external environment. Clark and Chalmers argue that these scenarios are not unique, and that we constantly rely on ‘environmental supports’ for performing complex cognitive tasks (643). Evidence for this includes our use of pencil and paper, calendars, appointment and address books, and of course, the digital computer in its many varieties. In these cases, the brain is performing some cognitive tasks while distributing others to the environment.

 To bridge the gap between the claim that cognitive processes are distributed with the hypothesis that cognitive processes are continuous with the environment, Clark and Chalmers propose the Parity Principle. This principle generalizes that, if some part of the environment functions in a way that a solely intracranial cognitive process does, then that part of the environment is constitutive of a cognitive process. Specifically, a part of the environment is cognitive if it plays the right sort of causal role in generating action (645). For example, because the use of pencil and paper to aid in calculating large sums augments intracranial cognitive processes devoted to computation, pencil and paper contribute to the functional role of those intracranial processes. In so doing, they become indistinguishable from intracranial cognitive processes, and thus cognition extends into the environment.

 Active externalism differs from the variety of externalism proposed by Putnam and Burge in that it emphasizes the causal role that elements of the environment play in determining our cognitive processes in the present (Clark and Chalmers 644-45). In Putnam’s Twin Earth thought scenario, two physically-identical people embedded in distinct socio-physical environments hold beliefs with different semantic content (Putnam 585-86). The thought scenario is meant to show that the semantic content of beliefs is determined by the environment and not anything intrinsic to a person’s neural states. Unlike active externalism, the external features that individuate belief contents are distant and historical, such as the linguistic community of which one is a part. Thus, the present state of the environment plays no role in fixing the content of our beliefs or driving our cognitive processes.

 The emphasis that active externalism places on the role of the environment in determining present cognitive states and processes leads Clark and Chalmers to propose that individuals and objects in the environment form a coupled system. Each component of the organism-environment system plays a causal role in jointly determining behavior. Since the environment is coupled to the organism, it has a direct impact on the behavior of the organism (Clark and Chalmers 644). For example, when a person uses a computer to perform mental rotation processes, the computer directly impacts the perception of the rotating shapes by allowing the individual to determine the compatibility of the geometric shape with the slot (Clark and Chalmers 644).

1. The Mind, Extended

 As Clark and Chalmers acknowledge, the HEC is compatible with a traditional internalist conception of mental states (e.g. beliefs, desires, and emotions). Consequently, they advance the extended mind hypothesis (EMH), which states that some mental states extend in to the world. They describe two thought scenarios which are intended to show that beliefs can be constituted by objects in the environment if those external objects play an active role in driving cognitive processes and guiding action (Clark and Chalmers 647). If this is correct, then it follows that (at least some) mental states are extended into the environment.

 First, we are asked to imagine Igna, on her way to see an exhibit at an art museum. Consulting her memory, Igna thinks that the museum is located on 53rd street. In response to this belief, Igna walks to 53rd street and finds the art museum. Next, consider Otto, who is suffering from Alzheimer’s disease. Because the disease impairs his declarative memory, he must rely on a notebook to serve as a memory storage device. Otto brings his notebook everywhere, writing and erasing information as needed. When he hears about the art exhibit he consults his notebook, which informs him that the museum is located on 53rd street. In response, Otto proceeds to 53rd street where he finds the art museum (Clark and Chalmers 647).

 This thought scenario is intended to show that Otto’s notebook plays the same role in guiding action as Igna’s memory does for her. The information in Otto’s notebook is always reliably present, available to consciousness, and available to guide action, in the same way as beliefs. The only difference between the two cases is where the information comes from that gives rise to their beliefs about the location of the art museum. Igna’s brain stores the information she needs to form beliefs about the museum, whereas Otto’s notebook stores the information that allows him to have the same belief. If this is correct, then Otto’s mind extends out to, and includes, the notebook (Clark and Chalmers 647).

 The second thought scenario introduces Twin Otto who is identical to Otto in every respect, except that in his notebook he recorded the location of the art museum as 51st street. When Twin Otto consults his notebook, he mistakenly proceeds to 51st street, where he is dismayed to find no art museum. Twin Otto’s belief guides his actions in the same way Otto’s belief does, irrespective of its falsity. The only difference between both of their beliefs is the external content. Thus, Clark and Chalmers arrive at the same conclusion that Putnam does, that the content of our beliefs is not restricted to the brain. From this, the authors conclude that since beliefs extend into the world, the mind as a whole is extended (Clark and Chalmers 648).

1. The Coupling-Constitution Fallacy

 Aizawa and Adams provide two of the strongest replies to the HEC and the EMH. First, they maintain that most arguments for both hypotheses commit the coupling-constitution fallacy (CCF). Proponents of HEC and EMH commit the CCF when they mistake processes in which cognition is embedded for processes that are constitutive of cognition. In doing so, they erroneously jump from the observation that since some environmental process X is causally connected to a cognitive process Y, that process X is a component of process Y (Aizawa & Adams 8). Moreover, arguments which appeal to the concept of a system do not elucidate the inference from causation to constitution. To say that a system is an X system does not entail that every component of the system does X. For instance, not every component of an audio system produces sound, nor does every part of a computer perform computations.

 Clark and Chalmers’ arguments for the HEC and EMH commit the ‘systems version’ of the CCF. Active externalism proposes a causal coupling between an individual and the environment. From this it is inferred that this coupling constitutes a system. Since every part of the system plays the same role in governing behavior as intracranial cognitive processes do, the coupled system is, “a cognitive system in its own right” (Clark & Chalmers 644). It is in this respect that cognition is said to extend into the world. However, the mere coupling of a process with the wider environment does not automatically extend that process into the environment, as in the previous examples of audio and computer systems. (Aizawa and Adams 9).

 Consider another example, the Watt governor, which regulates the speed of an engine by adjusting a throttle valve that supplies fuel to the engine. The Watt governor consists of weights mounted on a pair of spring-loaded arms that are connected to the engine throttle valve by a spindle. An increase in engine speed raises the arms through centrifugal force, which causes the throttle valve to close, restricting fuel flow. Likewise, a decrease in engine speed lowers the arms, which causes the valve to open. Thus, modulation of the valve aperture by the Watt governor regulates fuel flow, which constrains the engine speed (Aizawa and Adams 9; van Gelder 349). That is to say, the process of combustion that drives the engine is tightly coupled to the rotational speed of the arms. However, it does not follow from this that the process of combustion extends into the entire system (Aizawa and Adams 9).



*Figure 1*. The Watt Governor (van Gelder 349).

1. The Mark of the Cognitive

Aizawa and Adam’s second reply is that extended cognition theorists do not have a sufficient conception of what distinguishes the cognitive from the non-cognitive (9). Since Clark’s and Chalmers’ inference from causation to constitution is unfounded, it is arguable that parts of the environment merely support internal cognitive processes rather than constitute cognitive systems. In order to defend the HEC, the authors must provide criteria that distinguish between cognitive and non-cognitive processes. Clark’s and Chalmers' description of cognition is ambiguous, while other accounts of the HEC characterize cognition in terms of information-processing (Rowlands 8). While the latter is the received view in the cognitive and neural sciences, not all information processors are cognitive. Digital computers are information-processors, and yet one hesitates to consider specific implementations of digital computers (such as mp3 players, DVD players, mobile phones, etc.) as cognitive (Adams and Aizawa 22-3). Thus, cognition as information-processing casts too wide of a net to capture the uniqueness of actual cognitive agents.

 The subsequent section outlines how dynamical systems theory offers a conceptual framework for understanding the behavior of coupled systems in such a way that arguments for the HEC and the EMH can avoid the CCF. However, dynamical systems theory on its own does not offer a mark of the cognitive. While this paper makes no claims about the necessary and sufficient conditions for cognitive systems, it should be noted that Barandiaran and Moreno (2006) offer criteria for minimal cognition in dynamical systems terms. They contend that specific kinds of dynamic organization that adaptively sustain behavioral dispositions distinguish cognitive states and systems from non-cognitive ones (182).

1. Extending Cognition with Dynamical Systems Theory

 The failure of Clark and Chalmers’ arguments to avoid the CCF is due to their impoverished notion of systems. The following section provides a brief summary of dynamical systems theory (DST) and how it can be employed to defend the HEC and the EMH. DST is a set of mathematical concepts for understanding the temporal unfolding of dynamic systems (Rupert 50). A dynamical system is a set of quantitative variables that change continuously and interdependently over time according to laws that can be described by differential equations (Chemero 25). The state of a system is defined by the collective value of its variables at a given point in time, while the behavior of a system is its transitions between states. Change in a system often depends on external factors, called parameters (van Gelder 1998, 616).

 A dynamical system is described in terms of its phase space, or the set of all the possible states of a system (Chemero 36). A phase space is represented with a graph in which every point in the phase space lies on a trajectory. Trajectories show the evolution of the system through the phase space. A picture of the possible trajectories of a system allows us to visualize how small differences in the value of a system’s initial state can give rise to vastly different behaviors (Rupert 132). There are certain points in a system’s phase space, known as attractors, which the system will tend to converge towards over a long enough period of time. For instance, a marble dropped in a bowl will roll around until it comes to rest at the lowest point. This is a simple example of an attractor with a fixed equilibrium point. Alternatively, a system can have a periodic attractor, as with an idealized pendulum or planetary orbit. In both cases, the system oscillates between two states (van Gelder 1998, 627).

 DST can be distinguished from dynamical modeling, which attempts to understand change in real systems by applying the concepts of DST (van Gelder 1998, 621-2). For example, consider how a dynamical model of the previously-mentioned Watt governor explains its behavior. Recall that coupling between various components of the governor-engine system is responsible for regulating the engine speed. The angle of the weighted arms depends upon the engine speed, while simultaneously determining the flow rate of the fuel by regulating the valve aperture, which in turn modulates the engine speed, and so on. A dynamical model of the Watt governor requires a differential equation that will tell us how the rate of change of the arm angle changes depending on the current angle, how the angle has changed previously, as well as the engine speed (van Gelder 1995, 356). This equation describes the behavior of the governor given any arm angle and engine speed.

 However, the governor does not exist in isolation. It influences and is influenced by the engine, and so a more accurate picture of the governor’s behavior must take these interactions into account (van Gelder 1995, 356). Consider the engine and governor as separate but interacting systems. Since the current setting of the engine throttle valve depends upon the governor arm angle, it is a parameter of the governor system. Likewise, since the current arm angle depends upon the position of the throttle valve, it is a parameter of the engine system. This mutual relationship is called coupling, and the continuous coupling between subsystems can be viewed as a unitary system itself (Rupert 133).

 Altering the parameters of a system changes the entire dynamics of the system (Chemero 70). Thus, any change in engine speed changes the way the state of the governor changes (i.e. changes how the behavior of the governor unfolds over time) (van Gelder 1995, 357). Likewise, any change in arm angle alters the temporal unfolding of the engine’s behavior. Because of this coupling, the entire governor-engine system will settle into a state in which arm angle and engine speed remains constant, known as a fixed equilibrium point attractor. The phase space of the governor-engine system reveals that, despite different initial conditions the engine eventually settles into a constant speed. This is precisely what the governor-engine system was designed to do (van Gelder 1995, 357).

 There are several important points about this dynamical account of the Watt governor that can be brought to bear on the CCF reply to Clark and Chalmers. First, the direct mutual dependence between parameters and dynamical systems offers a robust conceptual scheme to back up the inference from the causal coupling of individual and environment to the claim that parts of the environment constitute cognitive systems. Otto's notebook is a parameter of the Otto-system, so that Otto's manipulation of the notebook is reciprocally coupled to specific neural processes. The reciprocal coupling of notebook and neural processes constitutes a coupled system, the remembering process (Menary 334). Changes to the parameter, or notebook, directly influence the overall behavior of the coupled system, such as when Twin Otto writes down false information in his notebook and walks to the wrong location.

 Second, decoupling the arm angle of the governor from the engine throttle valve would render the system unable to perform its designed function. Likewise, decoupling Otto's notebook from his neural processes would have significant consequences for the process of remembering, and by extension, Otto's future behaviors. This is what Clark and Chalmers pointed out when they stated that, “if we remove the external component the system’s behavioral competence will drop, just as it would if we removed part of the brain” (644).

 Of course, Watt governors seem vastly different from cognitive agents. One might object that it remains to be seen to whether a DST approach to cognition is even possible, and if it is, how much explanatory power it has. In fact, dynamical modeling has been adopted by some cognitive scientists, who remain optimistic that it offers a novel approach to cognition that can work alongside the traditional computationalist paradigm. Specifically, a form of dynamical modeling called coordination dynamics has met with some success in explaining empirical data. Coordination dynamics proceeds similarly to the aforementioned dynamical model of the Watt governor. The end result is a derivation of the dynamics of a system from descriptions of the non-linear coupling among the system’s elements (Chemero and Silberstein 132).

 To demonstrate the effectiveness of this methodology, consider an ingenious experiment which utilized coordination dynamics to explain spontaneous synchronization and de-synchronization of finger-waving in two subjects. The two participants were asked to sit across from each other with their eyes closed and move their fingers up and down. Each trial was divided into three segments in which the subjects were asked to either keep their eyes closed or open them while moving their fingers. When the participants had their eyes closed, their fingers movements were de-synchronized, or out of phase, with one another. When their eyes were open, their finger movements spontaneously synchronized. Once again, upon closing their eyes, both subjects’ finger movements de-synchronized. Previous research by J.A. Scott Kelso and others has shown such finger-waving movements are mirrored by activity in the sensorimotor cortex (Chemero and Silberstein 13). These results show that there is a spontaneous coordination of brain activity, behavior, and a source in the external environment.

 Kelso and the other researchers explained this interpersonal coordination in terms of coordination dynamics. This allowed them to abstract away from details such as how the finger movements modify incoming light, which impacts retinal cells, which in turn impacts neurons, which affect muscle movements that lead to rate-dependent changes in the speed of the other subject’s finger movements (Chemero and Silberstein 13). In fact, the researchers were able to model the dynamics of the coupled system with just one parameter, the state of the participants’ eyes. By using coordination dynamics, the researchers were able to explain how the environment drives behavior without reference to internal states at all.

1. The Collective Mind?

 This brief foray into nonlinear systems and quantitative modeling is not meant as a robust defense of the twin hypotheses of extended cognition and mind. Rather, it is meant to show that it is entirely possible to formulate a version of those hypotheses that does not commit the CCF. Avoiding that fallacy allows us to put aside the issue of the mark of the cognitive. Thus far, little has been said about the EMH. The foregoing dynamical systems reply to the CCF objection is intended as an equally viable defense of the claim that the mind extends into the environment. Although DST and dynamical modeling can be employed to describe the interactions between and within animal-environment systems, they have yet to be applied in explaining the extension of mental states and their content.

 There are alternative approaches, however. The remainder of this paper focuses on Deborah Perron Tollefsen’s (2006) account of collective intentionality. Her argument proceeds directly from Clark and Chalmers’ arguments for the HEC and the EMH. First, she distinguishes between the coupled individual-artifact systems (what she calls solipsistic systems) proposed by Clark and Chalmers, and collective systems that are composed of individual coupled agents. Then she describes a thought scenario involving a collective system that she takes to be functionally equivalent to a solipsistic system such as the coupled Otto-notebook system. This collective system is composed of Olaf and his wife Inga, who have been married for 30 years. Because Olaf is rather absent-minded, he forgets information such as appointments, phone numbers, and addresses. Since Olaf and Inga spend much of their time together, Inga provides Olaf with any missing information he needs to function on a daily basis.

 Tollefsen argues that Inga plays the same role for Olaf as Otto’s notebook does for him. Like Otto’s notebook, Inga is readily available for Olaf to consult; the information she exchanges with him is automatically endorsed, and has been endorsed by Inga at some point in the past. Tollefsen notes that the Olaf-Inga system could be construed as a simple transference of information between two disparate systems. In response, she proposes that the retrieval and reconstruction of information is accomplished jointly. Perhaps Olaf remembers a person’s last name, while Inga can only recall the first name. Or, Olaf remembers where they first met, whereas Inga can only remember why. Through processes of joint deliberation and discussion, Olaf and Inga can retrieve and reconstruct information that plays an active role in their collective cognitive processes and behavior.

 To support her claims, Tollefsen cites the phenomenon of transactive memory, in which groups of individuals collectively encode, store, and retrieve information (145). At first glance, it seems that simply asking a stranger a question is sufficient to form a collective memory system. However, several requirements constrain the kinds of interactions that can be said to involve processes of collective memory. First, the individuals that comprise a collective memory system have to know where the information is stored as well as the storage capacities of the other individuals in the system. Second, experts are responsible for the storage and retrieval of domain-specific information, while other members direct new information to the relevant specialists. Finally, collective memory systems form over time through the interaction of their constituent individuals.

 The notion of a collective system raises a number of concerns about the locations and boundaries of the individual minds that comprise the system. Tollefsen brushes aside questions such as, Is Inga part of Olaf’s mind? Where do Olaf and Inga’s individual minds end and their collective mind begin? Questions such as those arise because of the assumption that the mind is a substance or object with an individual locus of ownership. On the contrary, the mind is simply a collection of various processes and states. It is a category mistake to consider the mind to be a substance or thing, just as it is a category mistake to wander through a university campus while demanding to know the location of the university.

1. Concluding Remarks

 This paper has attempted to save Clark and Chalmers’ arguments for the HEC and the EMH from the coupling-constitution fallacy and the charge that extended cognition and mind theorists fail to provide criteria with which cognitive and non-cognitive systems are distinguishable. A dynamical systems interpretation of Clark’s & Chalmers’ hypotheses, according to which individuals and the environment form non-decomposable systems, avoids the coupling-constitution fallacy. To support their internalist conception of cognition, Adams and Aizawa state that, “it seems reasonable to suppose that the science of cognition will resemble the science of physical, chemical, and biological processes. Such, at least, is our bet” (2001, 63). Yet, dynamical systems theory has been incredibly fruitful in modeling and explaining the physical, chemical, and biological sciences (Scott 4-12).

 Lastly, demanding a “mark of the cognitive” from a hypothesis that proposes a revolutionary conception of cognition and the possibility of new research programs is unwarranted. A conceptual, or non-empirically-driven argument, bears little weight against empirical claims such as the HEC and EMH. For instance, consider the case of Evolutionary Biology: While there is continual debate among philosophers of Biology as to what defines a species as well as the specific mechanisms that drive speciation, none of those arguments have stopped Evolutionary Biologists from investigating the mechanisms of biodiversity. Likewise, a real test of Clark’s and Chalmers’ hypotheses must come from empirical support and the extent of the hypotheses’ explanatory power.

Works Cited

Adams, Fred, and Aizawa, Ken. "The Bounds of Cognition." *Philosophical Psychology* 14, no. 1 (2001): 43-64.

Adams, Fred, and Aizawa, Ken. “Why the Mind is Still in the Head.” In *Cambridge Handbook*

 *of Situated Cognition,* edited by Philip Robbins, and Murat Aydede, 1-36. Cambridge: Cambridge University Press, 2008. Electronic Pre-print.

Barandiaran, Xabier, and Moreno, Alvaro. “On What Makes Certain Dynamical Systems Cognitive: A Minimally Cognitive Organization Program.” *Adaptive Behavior*. 14 (2006): 171-185.

Chemero, Anthony. *Radical Embodied Cognitive Science*. Cambridge, MA: MIT Press, 2009.

Chemero, Anthony and Silberstein, Michael. “After Philosophy of Mind: Replacing Scholasticism with Science.” *Philosophy of Science*. 75 (2008): 1-27. Print.

Clark, Andy, and Chalmers, David. "The Extended Mind." *Philosophy of Mind: Classical and Contemporary Readings*. Comp. David J. Chalmers. New York: Oxford University Press, 2002. Print. 643-651.

Couzin, Iian. “Collective Cognition in Animal Groups.” *Trends in Cognitive Sciences*. 13.1 (2009): 36-43. Print.

Menary, Richard. “Attacking the Bounds of Cognition.” *Philosophical Psychology*. 19.3 (2006): 329-344.

Putnam, Hilary. “The Meaning of “Meaning”.” *Philosophy of Mind: Classical and Contemporary Readings*. Comp. David J. Chalmers. Oxford: Oxford University Press, 2002. Print. 581-596.

Rowlands, Mark. “Extended cognition and the mark of the cognitive.” *Philosophical Psychology*. 22.1 (2009): 1-19. Web. 18 May 2010.

Rupert, Robert. *Cognitive Systems and the Extended Mind*. Oxford: Oxford University Press, 2009. E-book.

Scott, Alwyn. *The Nonlinear Universe: Chaos, Emergence, and Life*. Berlin: Springer, 2007. E-book.

Tollefsen, Deboah. “From extended mind to collective mind.” *Cognitive Systems Research*. 7 ( 2006): 140-150.

Van Gelder, Tim. “What Might Cognition Be, If Not Computation?.” *The Journal of Philosophy*. 92.7 (1995): 345-381.

Van Gelder, Tim. “The Dynamical Hypothesis in Cognitive Science.” *Behavioral and Brain Sciences*. 21 (1998): 615-665. Print.

Ward, Lawrence. *Dynamical Cognitive Science.* Cambridge, MA: MIT Press, 2002. E-book.