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Authors

Somers, Sterling
Jeanson, Francis

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Sterling Somers (sterling@sterlingsomers.com)
Institute of Cognitive Science, Carleton University, 1125 Colonel By Drive
Ottawa, On., Canada

Francis Jeanson (fjeanson@connect.carleton.ca)
Institute of Cognitive Science, Carleton University, 1125 Colonel By Drive
Ottawa, On., Canada

Abstract

Using a hierarchical-systems analysis, this paper supports the orthodox view of the mind. We claim that the orthodox mind – bounded by brains or bodies – is organized into various system levels, each of which is emergent from the dynamics of level below it. We see the extended mind hypothesis as borrowing terms from a high-level system of the orthodox mind and applying it to interactions between high levels of separate hierarchical systems, without providing any lower levels on which to ground it.

Keywords: transduction, extended mind, levels.

Introduction

Following Herbert Simon's analysis of complex systems (Simon, 1962) and Newell's related chapter on system levels (Newell, 1990); this paper supports the orthodox view of the bounds of the mental (the mental is bounded by the body) in a non-question begging way. Recognizing that minds (high-level systems, defined by lower-level dynamics) interact with other minds or objects in the world, not through direct interaction of mind-level (high-level) systems, but through a physical intermediary at a lower-level, we show that it is incorrect and misleading to incorporate within our definition of mind that which extends with other minds or external objects. The orthodox mind is grounded empirically on the levels which emerge from some fundamental level, while no such hierarchy exists in support of minds hypothesized to extend into other minds or objects. In this paper we argue that cognitive systems are bounded by the transduction processes that give rise to the dynamics upon which the hierarchies are based.

Dynamics

In Simon's paper on complex systems (1962), he argues that most (if not all) complex systems are hierarchical systems: a system "that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem" (p. 468). As Simon points out, hierarchical systems share a common trait: near decomposability. Near decomposability simply means that higher-level subsystems of a hierarchy are composed of lower-level subsystems. As a result, higher-level subsystems can be decomposed into the lower-level subsystems that make them up. One thing that follows from this is that higher levels have longer times scales, as the events at higher levels depend on the events of lower levels. On the larger time scale of the higher-level subsystem, the subsystem description of the lower level becomes superfluous, provided that the high-level subsystem is decomposable. This feature of hierarchies is what Newell refers to when he describes a `strong' system level. While for Simon hierarchical systems all share the property of near decomposability, Newell suggests that some system levels can be 'weak'. Essentially, a system level is weak when it does not perfectly predict behavior at the level to which it belongs in the hierarchical system. A weak level may be simpler than sublevels but if it is not decomposable into the sublevels, one may have to recruit the sublevels in order to explain certain phenomena. Important in Newell's and Simon's analysis is that for each system-level there is also some appropriate language for describing that level.

Each subsystem (system-level) in a hierarchy is characterized by the interactions of the components of that system-level. The stability of these interactions, what we refer to as the dynamics of the system-level, is what allows us – in physical systems at least – to identify those levels. A system-level, defined by its dynamic, should always be distinguishable via some observational measure. Consider, for example, a tornado[1]. The dynamics of a tornado (e.g., the interaction of the air molecules) can be visibly identified from the surrounding system (non-tornado air). A tornado is, then, a plausible candidate of an example of a hierarchical system. At a low level there are interactions between air molecules which, presumably, are travelling at certain speeds, and following certain paths, etc.; at an intermediary level we may distinguish small localized wind currents which are formed by aggregates of coherent molecules; while at an even higher level there is the entire tornado. The description of a tornado in hierarchical terms is particularly useful when high-level. Longer time scale analysis allows the identification, say, of its general location and itinerary over time and monitor or even predict its destructive effects. Without this high-level, low-frequency description it would be nearly (if not actually) impossible to mathematically describe the activity of the tornado throughout its lifetime with a system analysis at the molecular level (of course this does not include the possibility of accurate simulation). In the particular case of

[1] Simon's own example is of an organelle in a cell.

tornados, however, experts have found it notoriously hard to determine from global properties alone the future location and size of these natural phenomena. Therefore, these may not qualify for a strict high-level analysis for the reason that their higher-level qualities do not belong to a hard level. In reality, an accurate prediction as to their lifetime, precise trajectory and growth/dissipation rates may require higher-frequency levels of analysis combined with simulation. Indeed, it has become increasingly clear over the past decades that complex (non-linear, multi-variate) lower level phenomena that may be mathematically intractable analytically can be solved via computer simulation given adequate model pre-conditions. Hence the degree to which a level of analysis gives rise to a set of identifiable or ascribable features that have reliable (stable) implications for the description and prediction of the system's behaviour *at that level* will ultimately determine the degree to which this level is strong or weak. This suggests that determining the degree of strength of a level is *relative* to its degree of reliability. Notably, this comes in sharp contrast with what we would call *realism* about system levels. Although we do not dismiss the fact that hierarchical systems are physical systems, we do not need to (nor want to) talk about how real any level of the system is; especially given the lack of criteria which could tease apart those layers that manifest real phenomena from those that do not. Instead, we want to emphasize the sufficiency of arguing in terms of *levels of analysis* within their corresponding language. In particular we will show how the degree of reliability that a level of analysis offers, which determines its degree of strength, can be evaluated based on the types and number of errors it cannot address.

Neurons to Minds

Newell's chapter on system-levels provides a good discussion of the hierarchical system of the mind. Without reproducing his work here, we will provide a brief overview of what Newell talks about in that chapter.

From Unified Theories of Cognition, Newell's chapter, *Human Cognitive Architecture*, aims to describe the system-levels of the hierarchical system of human cognition. He does so by outlining the various time scales at which it is appropriate to study the system-levels of the human cognitive architecture, organizing the time scales into time bands: biological band, cognitive band, rational band, and social band. Each of these time bands are subdivided into the various system-levels of the human cognitive architecture: neuron, neural circuit, deliberate acts, operations, unit tasks, and so on. Newell describes the various system-levels in terms of the interactions of their components. For instance, Newell explains how, through the interaction of single neurons at a frequency of ~1ms, the emergence of neural group behavior arises (neural circuit) at the frequency of ~10ms. The story goes on, further and further up system-levels, eventually leading to operations, unit tasks, and tasks. (Newell, 1990) Newell's discussion reminds all of us within the cognitive sciences of what we all keep at the back of our minds (assuming materialism), that minds are not abstract entities but are, rather, grounded in the physical (as neurons).

While, as mentioned above, there should be languages which describe each system-level, it seems that no such agreed upon language has been described in cognitive science. While there are many candidate languages such as intentionality, production systems, information processing, dynamical systems etc., it's not clear that the candidate languages are either complete, that they can be applied to all system-levels of the human cognitive architecture or that they, taken together, handle all relevant levels. While we offer no analysis of mind-level languages, we do believe that most of these languages can play a useful role in the analysis of what Newell calls the Cognitive and Rational band. We assume, for the purposes of this paper, that all such languages can be equally applied to an abstract 'mind-level'(i.e. the point at which we begin to identify minds abstracted from their physical components, or the interaction thereof).

Problems with the Extend Mind Hypothesis

We see the Extended Mind Hypothesis (EMH) as a sort of systems theory. Like both Simon and Newell, proponents of EMH seem to delimit the mind by the dynamics of mind-level components. An obvious example of this is Dynamical Systems Theory (DSTs) which gives temporally based mathematical descriptions of interactions that "span the nervous system, the body, and the environment" (van Gelder & Port 1995, p. 34). In a different manner Clark and Chalmers (1998) use intentional terms to capture a relationship between components of the mind. They aim to show how, using the language of belief states, that the dynamics of components of the orthodox mind (the one bounded by brains or bodies) are functionally equivalent to dynamics of components in a mind that spans bodies and objects in the world. In their famous thought experiment, Otto, an amnesiac, relies heavily on his notebook as a source of information that he would have otherwise forgot. Clark and Chalmers show how, if the information in Otto's notebook can be considered beliefs, the notebook is functionally equivalent to a normal person's memory.

Critics of the EMH defend the orthodox view by appealing to differences in types of processes, or a special form of representation involved in cognitive processing which does not, as a matter of contingent empirical fact exist outside the brain (Adams & Aizawa, 2010). However, without appeal to these, we aim to show in the following how interaction between what has been traditionally viewed as different systems always occurs at a physical level and that there is no mind-level dynamics which captures both the physical-level components of separate hierarchical systems, as well as the physical-level components which mediate their interaction.

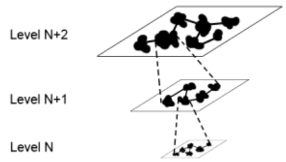

Figure 1: A hierarchical system showing how components of higher levels are defined by the interaction of components at a lower level.

As an illustration, let us first develop a picture of mind and notebook interaction in accordance with hierarchical systems theory. Figure 1, is an illustration of a hierarchical system and you can assume as many layers as you'd like until the top layer captures what is meant by 'mind', such that the components there within are whatever the components of a mind are. What those components are exactly is not important for our purposes here.

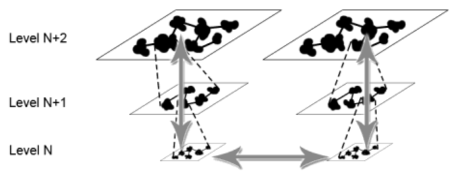

Figure 2: Two hierarchical systems interacting at a low-level.

Figure 2 is an illustration of what happens when two hierarchical systems interact. Consider, for example, what happens when an agent and a notebook interact. Let's assume, for the purposes of this illustration, that intentional terms adequately capture a system-level. In the notebook this would be some sort of information such as, 'MOMA is on 53rd Street'. What we can observe with the hierarchical system analysis is that 'MOMA is on 53rd Street' is a product of ink markings, in a certain configuration (the down arrow). Without going too low-level, the normal way for notebook-to-mind communication to happen is that light bounces off the paper, reflects differently when it hits the ink, and then eventually enters your eye. Once they hit the eye, dynamics of the lower levels instantiate the dynamics of the higher levels (the up-arrow), and we can use terms like 'belief' to summarize this interaction. The accuracy of that explanation aside, we can observe that interaction between the notebook and hierarchical cognitive system occurs at a low, physical level. In our view, this is the correct understanding of how systems interact.

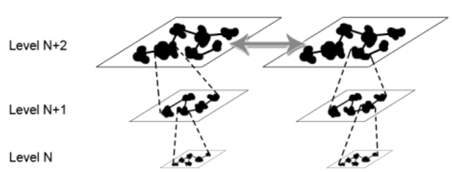

Figure 3: Two hierarchical systems interacting at a higher-level.

Figure 3 illustrates what EMH proponents seem to support: direct high-level interaction in which, using the same example, belief states in a notebook (allowing that such a thing makes sense) affect mental states. For example, 'MOMA is on 53rd Street' as written in the notebook directly influences Otto's belief state. Our claim is not that descriptions of this kind of interaction are not useful metaphorical shorthand but rather that the dynamical interaction they seemingly summarize does not exist. While it is convenient to talk about the contents of a notebook, say the sentence, 'MOMA is on 53rd Street'; interacting in some belief-state-to-action calculus, it is inappropriate to suggest that such an interaction defines an interaction between components of a mind-notebook system.

Accepting (for the moment) that the intentional stance (Dennett, 1987) is a plausible candidate of a weak level of (human) cognitive agents, it is understandable why we might want to borrow terms like 'belief' for describing other interactions as well. This usage of intentional terms occurs perhaps most notably by Clark and Chalmers (1998) when they suggest that Otto's beliefs are contained in his notebook. One benefit of borrowing high-level terms, which describe one hierarchical system, and using them to describe other types of interaction at a high-level, is that we get to use terms for which we feel we already have a grasp of. It also may be that the use of such terms actually helps us capture whatever it is we are trying to explain when we employ them. This is particularly true when the level of description we would otherwise have to use is low-level and/or noisy. Borrowing terms in this fashion can have certain informative advantages and under this interpretation we agree that EMH can be vindicated on this informational basis. It seems, however, that proponents of EMH have never favored this interpretation explicitly but have instead attempted to make a much stronger ontological claim regarding mental extension. The reason for this may be that a mere informational view of EMH significantly reduces the intellectual contribution that the hypothesis was originally attempting to achieve. As we will illustrate below, we believe that such ontological claims are unfounded and are even potentially detrimental to scientific pursuits in Cognitive Science because they undercut the lower-levels of the hierarchical system.

An example

Let's take as an example a digital computer. The digital computer is a favourite example in Cognitive Science and fits perfectly for our purposes here because the digital computer seems to be engineered to have decomposable system levels in the way described by Simon. If we draw upon the already heavily used analogy between what Newell calls the Cognitive Band and might be referred to as the Software Band in digital computers, we can see that software-level descriptions (e.g., interactions between certain programs) subsume hardware descriptions. This works well in digital computers because the linkages between the levels have been engineered to be decomposable. In brains, the analogous linkages are in fact linking theories which attempt to describe the relationship between higher and lower levels. Perhaps one reason Cognitive Science is slow in developing theories of the dynamics of the cognitive (the interactions of the cognitive machine, if you will) is that the mental is a weak level and thus components of the cognitive system cannot be isolated from the interaction of components at a lower level. Regardless of whether levels are weak or strong, in order to confirm the existence of some cognitive-level component, one needs to both identify the lower-level components, as well as the linking theories between the levels.

With a Software Band in place, describing interactions of the digital computer becomes more accessible. Most computer users can at least give high-level interaction descriptions (e.g., I pressed button x and the program did y) which correspond to progressively lower-level subsystems such as the programming-level, operating system level, and the hardware level. Now, to push the analogy a little further, let us suggest that there could be a science of computing[2]. To make this analogy work, let us also pretend that we do not already have the linking theories of computing, that there is some mystery about how computers work. Furthermore, let's set this illustration sometime in the cyberpunk future (as Clark might say) when word processing programs allow for collaborative work over the Internet. Could we argue that there is an extended word processor? Does it make sense to talk about word processor processes spanning the Internet? In order to answer those questions, let's first take a look at the hierarchical structure of a computer system.

Taking the hardware layer as the base unit of analysis, an interaction of logical gates (usually transistors) form groups of logical gates, or circuits. Interactions between circuits realize groups of circuits (circuit boards, chips, etc.). As you move up the layers, we eventually arrive at layers most people are familiar with: software layers. We can think of the software layers as composed of two layers: the programming layer and the user-interface layer. The programming layer is the layer at which programs are written, i.e. the code behind the user-interface layer. Again, it is the interactions or dynamics at the programming layer that realize the user-interface layer. We may also observe that these layers form hard layers. It is the consistency of the programming layer that makes the user-interface layer reliable. We can also give descriptions of the interactions from a user-interface level. For instance, in a word processor we can say that clicking the bold button caused the text to become bold.

Now let's imagine that a collaborative word processor where user-interface changes on one computer (WP^A) have parallel effects on another computer (WP^B) over the Internet. If a user on WP^A presses the bold button, turning text bold on their screen, the user on WP^B would have the same text bolded on their screen as well. One could imagine that in such a cyberpunk future the language used to describe relations between the two word processing systems would be highly correlated with the language used to describe a single system. It seems likely that one would simply say that the bold button on WP^A *caused* bolding on both WP^A and WP^B. Our argument is that while such language would be a convenient short-hand for describing the interaction of the two systems, it also undercuts the hierarchical system in a way that using a high-level language for describing an orthodox single system does not. This undercutting of the hierarchical system would have severe consequences in our imagined science of computing. To explain what we mean, let's carry the analogy a little further and try to explain what would happen if an error occurred in the interaction between WP^A and WP^B.

Suppose that whenever the name Otto appeared in a sentence the bold function did not work quite as it should. Let's imagine that in this scenario the text on WP^A's screen turned bold properly but the text on WP^B's screen did not. How will our imagined science of computing explain this? We can immediately see that any supposition of an extended word processing or extended computing system would have to be abandoned. Because the extended word processing system hypothesis posits that the base units of an extended word processing system is realized through the dynamics of the user-interface level across the internet (i.e. Figure 3 applied to our example), there exists no cross-internet layer below, in this view, which can account for this error. What in fact is the case is that information is encoded, sent across the hardware of the Internet, and decoded at the other end. The fact that WP^B's sentence did not get bolded can be explained either within WP^A's or WP^B's layers or at the lower level at which signal transmission occurs (a transmission error). The answer to both our questions above is: although it may be useful to speak *as if* there is an extended system, such a description would be misleading for our science of computing. Errors manifested at a high-level can only be explained through decomposition and, of course, that can only be facilitated when there are levels below to decompose to. In this example, ontological claims about extended computer systems are misleading for our fictional science of computing. In the same way, ontological claims about extended minds can be misleading, especially in fields like Cognitive Science that aims to provide linking theories between system levels of cognitive agents. Cognitive Science seems to rely on the fact there are emergent levels and that these levels are decomposable (in the weak or strong sense) to the various levels below.

But, you might object, that the two systems are extended across the hardware of the Internet. We admit that we would have to accept such an objection but only so far as we accept that, at some low-enough level, everything is extended to everything else. It would remain an open question as to whether cross-Internet dynamics would scale up. Furthermore it's not clear whether our imagined science

[2] Believe it or not, there are actually people who call themselves computer scientists!

of computing (of computer systems or word processor systems) is really after such descriptions at all.

Transduction as a boundary

Up to here we have defended the explanatory power of hierarchical systems. However, the identification of a system's boundaries cannot be assumed a priori. Instead, it is necessary to establish an adequate delineating process by which systems can be distinguished. For this, we propose that signal transduction can serve at a sufficiently low enough level to count as a mechanism of system boundedness. Signal transduction occurs when change in signal results in a change of dynamical properties. For instance, with an electrical motor we find a change from electrical dynamics to mechanical dynamics. From this we can make use of transduction as the fundamental level upon which hierarchical systems can be based. With transduction as a boundary, we do not need other mechanisms for boundedness. Furthermore, transduction avoids imposing limitations on the complexity of the system. Hence, errors that appear to occur at high levels can be accounted for by lower level interpretation as long as this level is identifiable via transducing boundaries.

This idea, we feel, is nothing new. We suspect that for most outside of the EMH debate, this idea has been implicitly accepted. A very similar idea, curiously enough, was presented by David Chalmers (2008), in the Forward to Andy Clark's book on the EMH, *Supersizing the Mind*. Chalmers suggests that perception and action forms the bounds of cognitive systems and are the interfaces of the mind from and to the world. This is precisely what we mean by transduction: the process that facilitates perception and action.

Transduction processes are fundamental (non-question begging) because the dynamics upon which they are based forms a plausible candidate for highest-level description of the interaction between hierarchical systems. Indeed signals of one form or another is a common currency between interconnected systems and the point at which the dynamics of these signals change, is the point at which the dynamics of the higher-levels begin to diverge. This divergence, we suggest, is precisely what separates systems and, following Simon (1962), the emergence of a hierarchy is what renders these systems intelligible.

Conclusion

Our argument in the preceding has been aimed at providing a principled account of the boundaries of the mind. Our claim is that transduction processes form the boundaries of minds because the dynamics which result from these processes form the basic system levels of the mind viewed as a hierarchical system. We have discussed how although it may be useful to talk *as if* minds extend into other minds or objects, we also warn that doing so may be misleading. We also demonstrated how borrowing high-level terms which describe one hierarchical system to describe other types of interactions, i.e. those between systems, can impede on scientific pursuits as it undercuts the structural levels which make up the separate hierarchies.

We accept that borrowing terms can be informative by providing a more intuitive understanding of the interaction between systems. We also accept the point made by dynamical systems theorists, phenomenologists, and the situated cognition folks, that we have to, in our analyses remember that the mind is tightly coupled with its environment. What we reject, however, is the ontological claims that the mind (as an abstract entity, grounded in the physical) is extended with objects in its environment or other minds. Although a notebook may function as if it were a belief storage device, beliefs themselves are entities of the hierarchical system of the mind, dependent on the subsystems which realize them. In so far as an analogous entity can be realized on a piece of paper (and we suspect that they cannot), that entity would be a product of its own hierarchy, communicated at a low-level (as some complex of signals) between different systems.

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