Avant. The Journal of the Philosophical-Interdisciplinary Vanguard
Volume II, Number 1/2011 www.avant.edu.pl

Breathing new life into cognitive science

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Abstract

In this article I take an unusual starting point from which to argue for a unified cognitive science, namely a position defined by what is sometimes called the 'life-mind continuity thesis'. Accordingly, rather than taking a widely accepted starting point for granted and using it in order to propose answers to some well defined questions, I must first establish that the idea of life-mind continuity can amount to a proper starting point at all. To begin with, I therefore assess the conceptual tools which are available to construct a theory of mind on this basis. By drawing on insights from a variety of disciplines, especially from a combination of existential phenomenology and organism-centered biology, I argue that *mind can indeed be conceived as rooted in life, but only if we accept at the same time that social interaction plays a constitutive role for our cognitive capacities*.

Introduction

The computational theory of mind is surely one of the biggest scientific success stories of the 20th century. It first emerged against the backdrop of a behaviorist establishment that rejected all study of the inner workings of the mind as unscientific, and yet it managed to convincingly demonstrate that the opposite was in fact the case. Computationalism made it conceivable for the first time that mental phenomena are a potential target for modern scientific study. In addition, it showed that it is possible to develop a systematic research program by bringing together a variety of disciplines under one shared hypothesis, in this case the idea that cognition is a form of computation. The trick was to conceive of the burgeoning field of computer technology not merely as a means for cognitive science, but as a target for study in its own right as well. Far from being vague and unscientific, the computational theory of mind had the advantage over previous theories in psychology of being securely founded on the formal principles of artificial intelligence.

However, as soon as the idea that the mind is indeed a valid target for serious scientific study had become more widely accepted, voices of dissent against the foundations of the computational theory of mind began to make themselves heard. Starting with Dreyfus' attack on symbolic AI in the '70s, followed by the connectionist movement of the '80s, and then continuing with the dynamical and situated robotics approach of the '90s, the originally narrow scope of cognitive science has continually been expanded. Today we are in a situation where numerous alternative approaches to computationalist cognitive science are clamoring for attention, and it is not uncommon for researchers to combine them into a loosely knit framework. In fact, even among some of the functionalists it has become fashionable to describe cognition as being embodied, embedded, extended and enactive. On my view, however, it is the enactive approach, in the sense in which it was conceived by Francisco Varela and colleagues[1], that pushes these developments to their logical conclusion, namely by treating mind as fundamentally inseparable from the existence of our subjective experience, its biological embodiment and its situatedness in the socio-cultural world.

Nevertheless, we should not forget that it is also thanks to the history of computationalist cognitive science that we now know much more precisely how the mind is fundamentally *not* like a computer. Take my laptop for instance: it can process inputs, store information and calculate the next outputs, and yet these events have absolutely no meaning for it. To put it simply, it does not understand anything at all, nor can it even care about this lack of understanding. In philosophy of mind and cognitive science this foundational issue makes an appearance every now and again. Today it continues to be debated under various related guises, e.g. the common sense problem, the symbol grounding problem, the frame problem, the hard problem of consciousness, and, most generally perhaps, the problem of meaning. But if it weren't for the failure of computationalist cognitive science to account for this aspect of mind, we would never have had such a clear understanding of how it is an essential part of our existence in the first place.

To be sure, it may be possible that this pervasive problem of how to explain meaning can eventually be solved by using the right kind of computational algorithms, for example by some form of 'meta-cognition'. Yet at the same time it is also an exciting possibility, as indicated by the growing popularity of alternative approaches to cognitive science, that a much more fundamental change in perspective is needed to advance on this issue. In the rest of this article I want to sketch the outlines of what such a change might look like.

1 E.g. Varela, et al. (1991); Thompson (2007); Stewart, Gapenne and Di Paolo (eds.) (2010).

Step 1: Solving the mind-body problem

The successful establishment of the field of cognitive science depended to a large extent on the field's ability to unite psychology and neuroscience under the umbrella framework of computer science. One of the main contributions of this constellation of disciplines is that it offers a scientifically workable solution to the mind-body problem: the personal / sub-personal distinction is conceived in terms of a software / hardware distinction.

In order for an alternative approach to cognitive science to be a serious contender for a new unifying theory of mind, it must also be able to address the mind-body problem in a satisfactory manner. Interestingly, there is a growing realization in the enactive approach that the mind-body problem is both more complex and simpler than has traditionally been supposed. First, it is important to acknowledge that on the so-called 'personal level' we can actually distinguish between several different perspectives, most crucially between the first-person (subjective experience), the second-person (dialogical I-You interaction), and the third-person (objective measurement) perspective[2].

Furthermore, so far cognitive science has always been working with a simple binary distinction between conscious and unconscious mental processes (i.e. the 'cognitive unconscious'). But careful phenomenological and psychoanalytical research reveals that we need to consider at least a tertiary distinction on the psychological level of description, namely between reflective experience (transitive awareness), pre-reflective experience (intransitive awareness), and unconscious processes (no immediate awareness)[3]. And, of course, there is also the physical level of description from the third-person perspective.

How does this more differentiated conception of human existence help us to solve the mind-body problem? The solution is centered on the pre-reflective level which had been previously hidden behind the absolutism of the mind-matter distinction. We may be able to spend significant parts of our existence in the reflective mode of the thinker, yet at the same time careful investigation of our experience shows that these moments are merely temporary excursions. Where do we exist the rest of the time? An answer developed by the phenomenological tradition, and taken up the enactive approach to cognitive science, is that we are always already practically engaged in our lives. This is the experiential realm filled with purposeful striving, temporal flows, ambiguous moods, sense-making, bodily feeling, and so forth. In a word, the phenomenon of life refers to the constitution of our 'lived' (from the German word *erlebt*e) existence, which is practically embodied and meaningfully situated in a world.

2 See, e.g., Zahavi (2005), Petitmengin (2006) and Stawarska (2009).
3 See, e.g., Zahavi (2006), Gallagher and Zahavi (2008, Chapter 3) and Fuchs (in press).

At the same time we know that this experiential or phenomenological aspect of life does not give us the complete story. Modern science has come a long way to reveal the many intricate material processes at work in the living body. There are metabolic cycles, energy transfers, cycles of growth and decay, chemical synthesis, neural firings, and so forth. In other words, any modern understanding of the phenomenon of life also has to take into account the organization of our biological body. Here we are thus confronted with yet another variant of the famous mind-body problem. But notice that in this case there is at least the advantage of a sense of a conceptual unity: both phenomenology and biology are interested in the study of life. And more importantly, we know from direct experience that there is an ontological unity as well. To put it differently, my living body does not only exist as an external object to biological science; I exist as this body. I experience that I *am* this living body during my practical engagement with the world, as a scary trip to the doctor can easily reveal.

This personal insight, which everyone can verify for themselves, informs one of the core tenets of the enactive approach, namely that *the material manifestation of my body as a living body cannot be separated from the experiential manifestation of my body as a lived body.* On this view, in contrast not only to the modern variants of Cartesian mind-body dualism but to other embodied approaches to cognitive science as well, the mind is not only embodied in a living body; *the living body is also 'minded' by a lived mind*. This intertwining of biological life and mental life is perhaps the most radical implication of the life-mind continuity thesis.

An important step toward dissolving the traditional mind-body problem can therefore be accomplished by fine-tuning the conceptual and phenomenological lenses we use to study the problem. The absolute explanatory gap can be relativized by the phenomenon of life into a 'body-body problem'[4]. To be sure, this refocusing can only be the very beginning of a new science of mind. What made early cognitive science so successful is that AI and computer science stepped up to the challenge and turned the philosophy of functionalism into a workable scientific research program in terms of the computational theory of mind. What could play a similar role in this case? It would seem that biology as the science of life would be naturally suited for this job, yet unfortunately this is not immediately so. While we are in need of a theory of the living body as such, i.e. a theory of the organism, it turns out that modern biology has largely been preoccupied with anything but the organism itself. On the one hand, it has focused on the study of sub-organismic processes, most notably related to genetics, and on the other hand, it has focused on super-organismic processes, especially Darwinian evolution. Unfortunately, it seems that the development of a new science of mind cannot be accomplished without the development of a new science of life as well.

[4] Hanna and Thompson (2003).

In order to fill this gap in modern biology we can draw on theories of the living organism as they have been developed in relation to cybernetics. One of the central ideas is that a living being can be conceived as an autopoietic system, which essentially means that it is a system that is organized so that one of the results of its operations is the continued existence of that system itself[5]. The classic example of an autopoietic system is a single-cell organism: if it weren't for the organized existence of the cell as a whole, the metabolic processes would not be able to continue and would quickly decay away. And at the same time, if the metabolic processes did not continue to operate, that would spell the end for the cell's existence.

We can find other instances of this co-dependency at several other biological levels of description. For example, we can think of the relationship between the cell's metabolic networks and its molecular components, whereby the networks are made out of the same components which their own activity produces. Another famous example is the co-dependency between the outer cell membrane and the inner metabolic networks, whereby the membrane regulates the necessary material and energetic exchanges and prevents the metabolic networks from diffusing and dissolving into the environment, while the metabolic networks produce the molecular components out of which the membrane is made. Other co-dependencies were added with the major transitions of evolution, but the essential idea remains the same in all cases. An organism is conceived as an autopoietic network of processes.

The concept of autopoiesis is a useful one with regard to the body-body problem for several reasons. First of all, it ensures that the concept of an organism is not merely used as a convenient label for what in the end is a reduction to the mere sum of its isolated parts. We can be certain that an organism exists in its own right, and not merely as a theoretician's product, because when we distinguish it as an autopoietic system we find that it has an *internal relation* to its own identity. In other words, it is what it is because of what it does, and it does what it does because of what it is. Another way of putting this in systemic terms is to say that an organism can be conceptualized as an autonomous system, namely as a self-maintaining, and more importantly, self-producing – and therefore self-distinguishing – network of processes.

Second, there are compelling reasons to assume that this internal relation of the organism serves as a reference point in relation to which internal and external events can show up as meaningful. Third, since the very existence of the organism is an ongoing achievement in the face of continuous decay and possible death, it is not too farfetched to argue that it is precisely this precarious situation which furnishes it with a perspective of concern. On this view, existential (metabolic) survival is regarded as the first of all values. Notice also that in this way we have left the functionalist frame-

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[5] See, e.g., Maturana and Varela (1987), Varela (1997), and Froese and Stewart (2010).

work of traditional cognitive science behind us: death, as the cessation of all function, cannot itself be viewed as another function without falling into paradox[6].

What these considerations nicely illustrate is that it is possible to work from the living body toward the lived body, just like we examined the living body from the perspective of the lived body. Although they are not immediately the same, the two sides of the body-body problem are not utterly alien to each other, either.

A further advantage of the autopoietic theory of the organism is that it is closely related to the mathematics of dynamical systems theory, which is neutral with regard to the ontological status of the modeled phenomena. Both biological and phenomenological events unfold in time, and this temporal structure can serve as a formal bridge between the two. In this unifying potential dynamical systems theory plays a similar role for this alternative approach as computer science did for traditional cognitive science. And yet there are several reasons for preferring the former: (i) dynamical systems theory provides a more general mathematical framework (even a computer is a kind of dynamical system, although of a peculiar discrete type), (ii) it allows us to do better justice to the continuous temporal changes of the phenomena at multiple timescales, and (iii) it is already the standard mathematical language of the natural sciences. In addition, and this is especially important in relation to cognitive science, it can prevent us from formulating explanations that are mistakenly over-psychologizing phenomena at inappropriate levels of description, such as the pre-reflective, metabolic or neural levels[7].

Step 2: Bridging the cognitive gap in theory

In the previous section I have introduced the ingredients for a unified cognitive science, although the interdisciplinary constellation of this alternative approach is quite distinct from the traditional one. Instead of triangulating between cognitive psychology, cognitive neuroscience, and computer science, it requires the development of new collaborations between existential phenomenology, organism-centered biology, and dynamical systems theory. On this view, Varela's pioneering proposal of neurophenomenology[8] is not sufficient; what is needed is a comprehensive *bio-phenomenology*.

Of course, the core disciplines of traditional cognitive science will continue to play an important role. Psychology is indispensable for good experimental design, neuroscience has the tools to investigate events at the sub-personal level, and computer science remains necessary for the practice of devising robotic or systemic models that serve as working proof of concepts. But while the methods of these disciplines

6 See, e.g., Jonas (1966), Weber and Varela (2002), Thompson (2004), and Di Paolo (2009).
7 See, e.g., Port and van Gelder (eds.) (1995), Roy et al. (1999), and Lutz and Thompson (2003).
8 Varela (1996).

continue to be relevant for the enactive approach, the way they are applied is given a different focus.

Similarly, not every wheel needs to be reinvented. For instance, in the field of artificial life there is a long tradition of modeling autopoiesis and the dynamical systems study of minimal cognition has also been ongoing for a couple of decades[9]. What the enactive approach contributes to these existing traditions is to make the mutually informing links between their interests and those of other disciplines, whether they already are a part of cognitive science or not, more explicit. In my own work I have been especially interested in the way in which insights from existential phenomenology, organism-centered biology, and agent-based modeling can be put into a mutually enlightened relationship[10].

But given this new starting point for cognitive science we are immediately confronted by a profound challenge: in what way can the insights of the life-mind continuity thesis be made more relevant to the specific interests of traditional cognitive science? That is, how can the study of adaptive living in the case of simple organisms be scaled up to the study of abstract cognition in the case of human beings? I have labeled this scaling problem, in reference to the explanatory gap faced by the functionalist thesis, the 'cognitive gap'[11]. However, I immediately hasten to emphasize that we are dealing with two fundamentally different kinds of gaps here: a gap of metaphysical proportions has been replaced by one of levels of complexity. All that needs to be done now is to demonstrate that the cognitive gap can be addressed in a systematic manner. In other words, while the cognitive gap of the life-mind continuity thesis refers to a coherent starting point which still requires further work, the explanatory gap of the mind-body problem refers to the lack of a starting point altogether.

The fact that the cognitive gap can indeed be overcome has been demonstrated by nature on two time scales. In historical time there was of course the evolution of modern *Homo sapiens* from proto-cellular origins. Unfortunately, however, the immense scale of this historical life-mind continuity makes it difficult to use evolutionary principles in order to apply insights gained at the level of organismic life directly to the level of human cognition. a more promising route may be the life-mind continuity which we can witness within the more manageable scale of our lifetimes, namely the development of a human being from its single-cell origins[12].

Yet, as the ever present nature-nurture debate demonstrates, the phenomenon of cognitive development continues to be a deep scientific problem. We will not get into

9 Beer (2003); McMullin (2004).
10 Froese and Ziemke (2009); Froese and Gallagher (2010). See also Rohde (2010).
11 Froese (2009); Froese and Di Paolo (2009); De Jaegher and Froese (2009).
12 An added advantage of this approach is that many developmental principles are readily expressed in the framework of dynamical systems theory (e.g. Thelen and Smith 1994; Smith and Thelen 2003).

the details of the nature-nurture dichotomy here[13]. For our purposes it is sufficient to accept that in many cases it is indeed difficult if not impossible to conceive how an *isolated* individual could learn complex behaviors without already being endowed with complex innate cognitive capacities (the most prominent example in traditional cognitive science being the case of language acquisition and the hypothesis of innate grammar). And yet at the same time we know that it is possible to enculturate non-human apes such as bonobos and chimpanzees by raising them in our social context[14]. And we further know that when a young *Homo sapiens* happens to be deprived of an appropriate socio-cultural context, it will sadly fail to develop the advanced cognitive capacities we have come to associate with the human species. In other words, it cannot be denied that specifically human cognition depends to a large extent on our involvement with others. If we want to bridge the cognitive gap we therefore need to take into account the role of sociality.

Traditional cognitive science has long recognized that a theory of the way in which we make sense of others is an important research goal. Right from the start computer science has provided a workable conceptual framework in the form of information theory. This theory, communication is essentially conceived as the transfer of information over a channel between a sender and a receiver, continues to be attractive to many since it fits neatly with the computational theory of mind. Indeed, the theory has been applied in many areas of cognitive science and has become the standard framework in mainstream biology. We will not enter into the debate about the validity of this theory here[15].

However, given the close relationship between the computational theory of mind and the information theory of communication, we can already expect that the latter will be faced by related problems. And indeed the field of social cognition in psychology has been haunted by an impasse analogous to the mind-body problem, namely the problem of other minds. This problem can be described as follows: given that the mind is distinct from the body, and given that we only receive the signals sent by the external bodies of others, then how do we ever come to know anything about the internal minds of others? For all we know, the computationalist cognitive scientists are forced to conclude, everyone else could be mindless zombies and we would never know the difference.

What this means in relation to the development of human cognition is that it is difficult to conceptualize how relations with others could be helpful unless the infant has already been innately provided with the cognitive tools to know (by theoretical inference and/or simulation) that the mindless automata moving around him could hypo-

[13] See Oyama (2000).
[14] Savage-Rumbaugh et al. (1998).
[15] But see, e.g., Maturana and Varela (1987, Chapter 8), Di Paolo (1997), and Shanker and King (2002).

thetically be intentional beings like himself. But the problem is that even if the infant was innately endowed with some of the best reasoning abilities, according to the theory of the computationalists it would still be faced with the almost impossible task to unravel the meaning of what must look like entirely arbitrary sounds, sights and movements.

These considerations are important for our current purpose because it is rather difficult to bridge the cognitive gap by appealing to social relations when our understanding of the relations to others is confronted by the problem of other minds. In what follows we will therefore develop a solution to the problem of other minds, and this will be done in an analogous fashion to the dissolution of the mind-body problem.

Step 3: Solving the problem of other minds

As noted before, careful phenomenological analysis reveals that the absolute distinction between the first-person perspective (experiencing myself as an 'I') and the third-person perspective (experiencing the other as an 'it') must be rejected as inadequate. It simply neglects the fact that we can also encounter each other in the second-person perspective (experiencing the other as a 'you'). There are of course distressing pathological cases in which people have limited or no access to enter the second-person perspective, such as in autism and schizophrenia. However, under ordinary circumstances we do not encounter the other merely as an 'it', although we can choose to do so as would perhaps a soldier who is aiming to kill his enemy or a surgeon who is operating on the body of his patient.

But under everyday conditions, while interacting with others, I do not perceive my fellow human beings in terms of zombie-like bodies with the theoretical possibility of having a mind. On the contrary, I directly perceive that the others around me are living-minded beings in their own right, and I perceive that they can perceive me in this way, too. This immediate perceptual realization of the other's lived embodiment precedes any kind of theoretical reflection[16].

There are two important consequences of this phenomenological analysis for our current discussion. First, it follows that the major theories of social cognition have been confined to an overly narrow view of sociality. They have focused on cognitive mechanisms for the acquisition of reflective knowledge about others, while the possible role of direct pre-reflective intuition of others has been neglected. Yet when I meet someone I do not have to theoretically posit the possibility of my interlocutor's mental existence; I immediately perceive the other's lived presence in their gestures. This kind of direct perception has typically been described in terms of empathy or sympathy in the phenomenological tradition. Note that once we acknowledge the existence of the pre-reflective second-person perspective there is no longer any problem

16 Zahavi (2001), Stanghellini (2004), Gallagher (2008), and Stawarska (2009).

of other minds as such, at least not on the reflective level traditionally targeted by cognitive psychology. And this brings us to the second point, namely that we are now faced with the challenge to explain the basis for our pre-reflective understanding of others.

One promising approach in this regard is to focus on the existence of a shared basis of understanding or a kind of common sense, literally speaking. Variations of this idea have been proposed by existential phenomenology, where it is typically described as the lack of an absolute 'self' and 'other' distinction during interaction at the pre-reflective level of the lived body. But these ideas have typically been expressed philosophically without any serious consideration of modern science. The traditional problem of other minds, on the other hand, is closely aligned to cognitive science, but is instead typically conceived in terms of how to explain the possibility of epistemic access between two metaphysically isolated minds. Fortunately, the life-mind continuity thesis opens up another promising option. If we accept the tenet that a living body is also a lived body, and if we can also show that interacting bodies become one body to some extent, then there is indeed a basis for directly sharing in each other's mindedness. This is one of the central ideas of my work, which I will call the *extended body hypothesis*.

It is not too difficult to show that, in theoretical terms at least, a concept of the living organism centered on the notion of an autopoietic system can be extended in the required manner. In fact, there is currently much discussion in the enactive approach to cognitive science which focuses precisely on this issue[17].

The first thing to emphasize is that a real autopoietic system cannot be thought in isolation from its environment. The membrane of a cell, for instance, preserves the cell not by simply isolating it, but rather by adaptively regulating environmental interactions. Of course, the cell must keep itself distinct and safe from the aversive influences of its environment in order to survive. And yet at the same time it must be open enough to engage the environment in a flexible manner and to find the nutrients which it needs to support its metabolism. On this view, the cell and the environment are not two isolated systems, but are intrinsically related in an asymmetric way (with the former depending on the latter for its existence). The upshot of this is that life is not some kind of independent substance, but a relational process[18].

Furthermore, the environmental side of this relation is not limited to chemical elements alone, but can include other organisms as well. In the case of the cell it is quite possible that its metabolism directly depends on the products of other organisms. And if some of those organisms also depend on the cell's excretions, then we have

[17] De Jaegher and Di Paolo (2007); Froese and Di Paolo (2009); De Jaegher and Froese (2009).
[18] Ruiz-Mirazo and Moreno (2004); Di Paolo (2005); Barandiaran and Moreno (2008); Barandiaran, et al. (2009); Virgo, et al. (in press).

established another cycle of co-dependency which relates these two organisms into a larger autonomous unit, an extended living body. In some cases this new autonomy can form a complex structural coherence so that we start speaking of multi-cellular organisms. The autopoietic theory of the organism can therefore be scaled up[19]. As an aside, note that if we accept that a living body and a lived mind are complementary phenomena, then here we have a partial response to the question of how we can be made out of individual living bodies (cells) and yet still experience the world from one unified perspective.

The metabolic formation of co-dependencies and multi-cellular organisms may serve as a general proof of concept for the extended body, but it does not help us directly with the task of finding a potential shared basis for our pre-reflective understanding of others. But can social interactions play a similar role perhaps? Again, organism-centered biology already has the basic theoretical resources we need. Rather than focusing on cycles of co-dependency in the chemical domain, such as autopoietic self-production, we simply turn our attention to the autonomous cycles in the way in which organisms relate to their environment. In the case of animals, for instance, we find a clear example that what the animal does depends on what it senses, and that what it senses depends on what it does[20].

And furthermore, given that a living body is also a minded body, each bodily movement is complemented not only by a change in sense perception, but also by a change in the lived body. Living, sensing, and doing are, through the mediation of the environment and the body, linked into one unified sensorimotor loop. On this view, the absolute distinction between perception, cognition, and action in traditional cognitive science (most famously expressed in the sense-model-plan-act framework) appears to be arbitrary. The enactive approach, more than any of the alternative approaches to cognitive science, has tried to do justice to the co-dependent nature of living, sensing and doing (and more generally of experiencing and moving) by employing the notion of *sense-making* in a literal way[21].

Since sense-making is based on the organism's sensorimotor loop and is therefore mediated through the environment, and the environment includes other organisms with their own sensorimotor loops, there is always the potential that there will be an interaction between the sense-making of distinct individuals. Moreover, it may happen that the organisms interact in a mutually responsive manner such that their sensorimotor loops become extended into a larger autonomous cycle. In addition to the usual sense-making, one organism's behavior leads to a change in the other organis-

[19] Maturana and Varela (1987); Froese and Di Paolo (in press).

[20] Out of all the ideas discussed in this article, the co-dependency between perception and action has been the most popular research topic among alternative approaches to cognitive science. See, e.g., Varela, et al. (1991); O'Regan and Noë (2001); Noë (2004; 2009); Barandiaran and Moreno (2006); Thompson (2005).

[21] Weber and Varela (2002); Thompson (2004); Di Paolo (2005); Sheets-Johnstone (1999).

m's sensations thus resulting in a change of its behavior which in turn modifies the sensations of this first organism and its behavior, and so forth. When the two organisms modulate each other's sensorimotor loop in this manner, they of course also modulate each other's sense-making activities. They are engaging in *participatory sense-making*[22].

The concept of participatory sense-making provides us with the theoretical foundation we need in order to explain the basis of our pre-reflective understanding of others. When our mutual interaction with others turns into an autonomous cycle in its own right, our bodies temporarily become one extended body via the dynamical mediation of our respective sensorimotor loops. And, once again, it is important to emphasize that according to the basic tenets of the life-mind continuity thesis *an extended living body entails an extended lived body.* What this means is that in the second-person perspective, when our bodies become dynamically entangled, we can take part in each other's experience.

In sum, we have argued that when we become aware of how we experience others during our interactions with them, we notice that at least on this existential level there is no problem of other minds. I can directly perceive others as living-minded beings like myself, and I can see that they perceive my likewise, too. Moreover, it is possible to give a coherent explanation for the possibility of sharing experience with others in terms of the life-mind continuity thesis and the extended body hypothesis.

Of course, what still needs to be explained is how the principles of participatory sense-making can be scaled up to account for the reflective levels of human social cognition, including the capacity for theorizing about other minds. But, more importantly, we have replaced yet another dilemma of metaphysical proportions by one of levels of complexity, and we are simply faced with a variation of the cognitive gap.

Step 4: Bridging the cognitive gap again, in practice

However, wasn't this detour through the problem of other minds supposed to provide us with a solution to the cognitive gap by making our relations with others an intrinsic element in support of cognitive development? If relations with others are also limited by a cognitive gap, then it may seem that we have hit another dead end.

But this worry underestimates the role played by pre-reflective second-person interaction in our relations with others, and it also underestimates the potential of the interaction process to autonomously organize our individual abilities. We can avoid the dead end if it is possible to demonstrate that, during its mutual interaction with others, a young infant's behavior can become appropriately entrained by the autonomous dy-

[22] This notion was introduced by De Jaegher and Di Paolo (2007) and has generated a lively discussion in the enactive community, e.g. Steiner & Stewart (2009); Gallagher (2009); Torrance & Froese (2011).

namics of the interaction process, and its internal bodily organization can be spontaneously configured to further sustain the interaction in a more flexible and adaptive way. That is, we need to show that, as long as the infant has the ability to mutually attune with others in the right kind of way, it can develop more advanced abilities through its interaction with others relatively automatically. And if the required sensitivity to others can also be achieved in the interaction itself, then the entire problem of the cognitive gap can be offloaded into a relational matrix distributed over self, others and the rest of the world.

Of course, it is one thing to show that this scenario is theoretically possible, and it is an entirely different thing to show that it is actually possible. In fact, given the major change in departure point which informs the scenario, an important first step will be to show that something like it is even possible in principle. This has motivated me to design a series of agent-based models of interaction which demonstrate that:

- An individual's sensitivity to others can result from interacting with others
- An individual's movements can be structured through interacting with others
- An individual's sensations can be structured through interacting with others
- An individual's body can be structured through interacting with others

It is beyond the scope of this paper to describe these modeling results and their dynamical systems analysis in more detail here, and I have done so extensively elsewhere[23]. What is important for our current discussion is that these models are concrete proof of concepts that it is possible for the cognitive gap to be systematically addressed through the spontaneously enabling dynamics of social interaction. Of course, the next step will be to continue this initial research by conducting actual psychological experiments, and some promising work in this direction is already underway[24].

Conclusion

All in all, the upshot of this article is that the computational theory of mind can indeed be replaced with an alternative framework centered on the notion of life-mind continuity, but only by incorporating the constitutive role played by sociality. I have argued that this alternative approach to a unified cognitive science has compelling advantages over other approaches. It is a workable scientific research program that stays

[23] The most detailed discussion so far can be found in my doctoral dissertation (Froese 2009), but some of the results can also be found in individual papers (e.g. Froese & Di Paolo 2008; 2010; in press-b).
[24] Auvray, et al. (2009)

clear of metaphysical conundrums, offers a closer alignment to human experience, and at the same time has sound mathematical foundations.

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