

teorema

Vol. XXX/2, 2011, pp. 00-00

ISSN: 0210-1602

[BIBLID 0210-1602 (2011) 30:2; pp. 00-00]

Embraining Culture: Leaky Minds and Spongy Brains

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RESUMEN

Ofrecemos un argumento a favor de la mente extendida basado en consideraciones acerca del desarrollo del cerebro. Defendemos que nuestros cerebros se desarrollan para funcionar en cooperación con los recursos cognitivos de nuestros entornos externos. Gracias a nuestra educación cultural, aprendemos a usar artefactos de manera fiable en la solución de problemas. Estos artefactos se convierten entonces en componentes de las rutinas cognitivas implementadas en nuestros cerebros. Así, este argumento viene a apoyar explicaciones de segunda generación de la tesis de la mente extendida [Rowlands (1999); Menary (2007); Sutton (2010)]. También defendemos que los argumentos a favor de la mente extendida basados en la complementariedad no se oponen a los basados en el funcionalismo, y que aquellos pueden aportar un necesario y hasta ahora infravalorado apoyo a la hora de defender la tesis de la mente extendida.

PALABRAS CLAVE: *Principio de la paridad, funcionalismo extendido, intuición marciana, complementariedad, poda sináptica, aculturación, ajuste cognitivo.*

ABSTRACT

We offer an argument for the extended mind based on developmental considerations. We argue that our brains develop to function in partnership with cognitive resources located in our external environments. Through cultural upbringing we are trained to reliably use artefacts in problem solving. These artefacts then become factored into the cognitive routines our brains support. We take this argument to support second wave defences of the extended mind [Rowlands (1999); Menary (2007); Sutton (2010)]. We also argue that complementarity and functionalist defences of the extended mind aren't opposed, but that complementarity considerations can provide much needed and hitherto under exploited leverage in defending EMT.

KEYWORDS: *Parity Principle, Extended Functionalism, Martian Intuition, Cognitive Bloat, Complementarity, Synaptic Pruning, Enculturation, Cognitive Dovetailing.*

INTRODUCTION

Human brains develop and grow in a cultural setting, and are shaped and sculpted by the cultural activities we acquire an expertise in from our

earliest days. We learn to engage in styles of thinking that exploit and manipulate tools and technologies we find around us, and in the process we acquire a brain that is wired to work in partnership with those tools and technologies. In what follows we will be developing an argument for the extended mind based on considerations of this kind from developmental neuroscience. We will argue that it is the plasticity of our brains that makes it possible for our minds to extend into the environment to incorporate the tools we use for thinking. It is because of the plasticity of our brains that these tools can become deeply interwoven and integrated into the workings of our minds. Our brains do not have a fixed functional architecture, but are sculpted and given form by the practices we repeatedly engage in. It is brain plasticity that allowed us as human beings to transform and augment our cognitive processes, and in the process to self-engineer our minds.

We take our argument for extended cognition to be broadly in the spirit of so-called “second wave” or “complementarity” accounts of the extended mind. These accounts stress the functional differences between internal biological processes and extended cognitive processes that criss-cross the boundary of brain, body and world. Extended cognitive processes yield a kind of cognition that couldn’t be accomplished just by relying on the naked brain alone, functioning in isolation from its cultural scaffolding. We will be arguing that it is the plasticity of our brains that made it possible for tools and props to transform the kinds of minds we have as humans.

Second wave accounts of the extended mind are sometimes advertised as avoiding some of the misinterpretations that “first-wave”, parity defences of the extended mind have inadvertently invited [Sutton (2010); Sutton et al. (2010), Menary (2010)]. We’ll argue in what follows that the first and second wave accounts are quite consistent with one another and mutually reinforcing. However the idea of complementarity is one that fits well with the developmental perspective we’ll be taking up in what follows, and it is for this reason that we’ve chosen to join the second wave.

With these preliminaries in place, we’ll briefly sketch the sections of the paper that will follow. In I, we begin by offering a brief overview of the debate surrounding the extended mind as it has unfolded thus far. It is old news by now that the debate surrounding the extended mind has run into something of a stalemate [see Rowlands (2009); Wheeler (2010); Sprevak (2010)]. We locate the stalemate in a familiar problem for functionalism: the problem of the inputs and outputs [Block (1978)]. We can’t see a way out of this problem for functionalists [though we find Wheeler’s (2010) revival of microfunctionalism an intriguing step in the right direction]. Thus rather than fight the battle for the extended mind on traditional turf, we turn our attention to a less explored strand of thinking in the literature on the extended mind that is concerned with complementarity.

Complementarity accounts, as we briefly explained above, take extended cognitive systems to be softly assembled systems made up of components that play very different roles, but that combine to make complementary contributions that enable flexible thinking and acting.¹ In II, we argue that it is precisely the fine-grained functional differences that matter when it comes to assessing putative cases of extended cognition. We finish up II by arguing that parity and complementarity accounts of the extended mind are quite consistent differing only in what they choose to emphasise. Complementarity accounts stress the different contributions made by internal and externally located items, arguing that it is precisely these differences that allow for the environment to play a transformative role in cognition. Parity accounts stress the coarse-grained functional similarity between internal biological processes and extended cognitive processes that span the brain, body and world boundary.

Having introduced the extended mind thesis (EMT) as we will understand it, we then turn to the main business of our paper which is to look to neural development for evidence that supports EMT (III). We end by using this argument to respond to one of the many challenges to the extended mind to be found in the work of Adams and Aizawa. They have argued that complementarity can at best establish the existence of extended cognitive systems, and they show that extended cognitive systems are one thing, the extended mind quite another. We will show how developmental considerations can be used to resist this distinction between extended cognition and extended cognitive systems (IV).

I. TROUBLES WITH (EXTENDED) FUNCTIONALISM

Much of the debate surrounding EMT has been focussed on the parity of the inner and outer in the production of cognitive behaviour.² EMT's friends have argued that we shouldn't treat location as a relevant factor when it comes to identifying the mechanisms that underpin human intelligent behaviour. Consider the much discussed case of Otto and Inga: the information in Otto's notebook plays the same causal role in guiding his action as Inga's biological memory does in the guidance of her actions [Clark and Chalmers (1998)]. We shouldn't treat the notebook differently just because it is physically located outside of Otto's head. The contents of the notebook work together with Otto's biological states in much the same way as Inga's biological memory works together with her other biological states in generating her behaviour. Given this similarity we ought to say that Otto's beliefs supervenes on mechanisms that include the notebook, and so span the brain, body, and world boundary.

EMT looks like a thesis that any philosopher of mind committed to functionalism ought to sign up for. For it looks to be a straightforward impli-

cation of the central tenet of functionalism that it is a state of mind's causal role that makes it the type of state that it is. The biological and the artefactual can coalesce to realise a type of mental state, so long as they work together to make the right kinds of causal contribution in the initiation and guidance of successful purposeful behaviour. Where the materials that make this causal contribution are located is not relevant, what is important is simply the job that these materials perform. Often these jobs can be performed better when the biological agent works in partnership with resources located in the environment beyond the boundary of skin and skull. Sometimes, and more on this below, the relevant tasks cannot be performed at all when we rely only on processes located within the biological skinbag.

However functionalist defences of the extended mind have temporally stalled because of an old problem that has long plagued functionalists: the problem of inputs and outputs. EMT says we need to individuate inputs and outputs in a way that doesn't foreclose the possibility of extended cognition. It has frequently been claimed however that the differences between internal biological processes and putative cases of extended cognition are so significant as to undermine the idea that they are functionally equivalent. The two sides in this debate are clearly operating with different criteria for individuating inputs and outputs, but who is to say which side is correct – the liberal criteria of EMT, or the stricter conservative criteria of its opponents [Rowlands (2009); Wheeler (2010)]?

Rupert (2004) and Adams and Aizawa (2001, 2008), for instance have challenged the idea of extended memory by arguing that extended memories don't fill the right kind of functional roles to count as memories. They have disputed that extended memories can really count as genuine cases of memory, since extended memories don't behave anything like biological memories. Extended memories don't exhibit negative transfer [Rupert (2004), p. 413], recency, primacy, and chunking effects [Adams and Aizawa (2001), p. 91; (2008), p. 61], signature features of human semantic memory. Adams and Aizawa also point out that Otto has to deploy specific motor and visual skills to access the contents of his notebook that are not needed by Inga when she accesses her biological memory [Adams and Aizawa (2008), pp. 68-70]. There are undoubtedly significant fine-grained differences in the functional roles of internal biological processes and processes that extend across the brain, body and world boundary ("extended" processes for short), but are opponents of EMT right to insist on such a *fine-grained* functional equivalence?

It might be thought that EMT has a way out by appealing to what Mark Spervak (2009) has labelled the *Martian Intuition*, the thought that creatures that are physiologically different from us can nevertheless share the same types of mental states with us. The Martian Intuition doesn't just allow for variation in physiology, it also allows for some variability in psychology. Just as we can abstract away from physiological differences in assessing whether

a creature shares our types of mental states so we can also abstract away from some (but of course not all) psychological differences. A Martian for instance might well be able to remember facts even though in psychological experiments it didn't exhibit negative transfer, or recency, primacy and chunking effects [Wheeler (2010), pp. 261-264]. Despite these non-standard methods of retrieval, still the Martian should be counted as remembering.

However playing the Martian Intuition card comes with its own costs [again see Sprevak (2009)]. The Martian intuition threatens to license a very liberal version of EMT, one that is so excessively liberal that it begins to look deeply implausible. Clark and Chalmers (1998) appeal to what have come to be called the "glue and trust" conditions in order to prevent the mind spreading too far and wide into the world. The glue and trust conditions say that an external resource counts as part of the mind only if the external resource is (1) portable (2) easily accessed and (3) automatically endorsed. However for each of these conditions we can readily conceive of a case of Martian cognition that fails to meet these conditions. We can imagine an insomniac Martian whose memories are easily accessed only if it has had a good night's sleep, but being an insomniac this rarely happens. We wouldn't want to say this Martian lacks memories just because the conditions for accessing them are rarely met. Such a conclusion would seem to run equally contrary to the spirit of the Martian intuition, and its allowance that creatures that are psychologically different from us can nevertheless share our mental states.³

It seems we must conclude that the Martian intuition is inconsistent with these constraints on extended cognition. Yet without such constraints the mind threatens to spread rampantly into the world. The kind of functionalism that licenses EMT is, it would seem, overly liberal and permissive in its attribution of mental states to stand a chance of being true. We could of course try to tame the Martian intuition so as to avoid such counterintuitive consequences [see Wheeler (2010)]. In order for such a strategy to succeed, we would need to identify criteria for the individuation of functional roles that are neither too liberal, nor too conservative. This takes us right back into the jaws of the problem of the inputs and outputs again. We will have to identify criteria for individuating functional roles that are acceptable both to friends of EMT and to its opponents if we are to avoid charges of begging the question.

We find Wheeler's recent revival of "microfunctionalism" a promising development in this direction, and one that is entirely in keeping with the argument we will make below [Wheeler (2010)]. Wheeler appeals to properties implemented by connectionist networks such as graceful degradation and flexible generalisation in developing an account of functional role consistent with EMT. It is an implication of his microfunctionalism that a system must realise a certain fine-grained functional profile if we are to count it as cognitive, but it is a functional profile that doesn't preclude the existence of ex-

tended cognition and extended minds. Perhaps Wheeler's microfunctionalist project can provide a way out of the problems that have hitherto bedevilled functionalist defences of EMT. We will however set aside this possibility in what remains of our paper. As we indicated in our introduction, we want to turn our attention to an alternative somewhat neglected set of considerations that have been appealed to in defending EMT.

II. THE COMPLEMENTARITY APPROACH

Functionalist defences of EMT have stressed the (coarse-grained) similarity in functional role played by internal, biological elements and externally located cognitive resources. They have tended to downplay the important of the fine-grained functional differences alluded to in the previous section, arguing that in assessing EMT we must abstract away from these differences. In keeping with the second-wave accounts of EMT, we will argue that it is precisely these fine-grained functional differences that matter when it comes to assessing putative cases of extended cognition. For whenever we find extended cognition, we find a kind of cognition that couldn't be accomplished by biological organisms relying exclusively on their biological inheritance. Instead we find biological processes that work together with environmentally located resources in ways that enable complex kinds of cognition the naked brain couldn't accomplish all by itself.

Consider the now classic example of the artist's sketchpad [van Leeuwen et al. (1999), discussed in Clark (2003), ch. 3]. The artist uses her sketchpad to try out ideas and refine them with results that she couldn't achieve by relying solely on internal mental imagery. The artist can, for instance, find multiple new interpretations in the images she conjures up in her sketchpad that constraints on mental imagery preclude her from discovering when she imagines an image in her head. This is nicely illustrated by Chambers and Reisberg's (1985) finding that when individuals are shown a picture of an ambiguous image for 5 seconds, a period too short for them to discover the alternative interpretation, and then asked to find the alternative interpretation through recall, subjects often fail to find the alternative image. However when asked to draw the ambiguous figure from memory, they can discover the second, alternative image in what they've drawn. People find it very hard to find different interpretations in their mental imagery, a difficulty they don't have when presented with a picture on a page. The sketchpad also permits the artist to try out her ideas and progressively refine them based on online feedback. She can create an initial outline and then sketch and re-sketch until she gets the result she is looking for. The process of give and take that unfolds between the artist and her sketchpad allows her to explore a space of possibilities she couldn't investigate by imagining the drawings in her mind's eye. Mental im-

agery is constrained in all kinds of ways that the artist gets around by means of iterated perception-action cycles in which the artist's creative thinking literally takes shape in the external media she is manipulating.

Consider as a second example mathematical reasoning. What is it about the human brain that enables us to excel at mathematical reasoning? Stanislas Dehaene and colleagues have shown in a series of striking studies that precise numerical reasoning may depend on language-specific representations of numbers. It is our learned capacity to use number words that has enabled us as humans to reason about exact quantities. In an fMRI study, Dehaene and colleagues found that performing exact calculations activated areas of the left inferior frontal lobe associated with speech, while the performance of approximate calculations by contrast activated bilateral parietal areas associated with visuo-spatial reasoning [Dehaene et al. (1999), pp. 971-2]. What this, and other findings suggest [see Clark (2008), §3.4 for discussion] is that reasoning about precise quantities is hybrid in nature, a competence we have when the brain works in partnership with human symbolic culture. We start off in development with an intuitive sense of quantity and its additive nature, and onto this "kernel of understanding are grafted the arbitrary cultural symbols of words and numbers" [Dehaene (2007), p. 41].

In both of these examples an environmentally located resources (the artist's sketchpad, human cultural symbols) enhances and augments our cognitive capacities, enabling us to achieve types of cognition that we couldn't achieve by the use of internal biological processes functioning all by themselves [Rowlands (1999)]. The externally located environmental resources have very different properties that allow these elements to make very different causal contributions to the overall cognitive process. We would argue that it is these different properties that play a transforming role in the kinds of cognition humans can achieve, making it possible for us to transcend the limitations of our biology. Human biology and human culture mesh together and become deeply integrated, and each makes its own distinctively different, but complementary contribution to achieving the complex forms of cognition we find in humans.

We have suggested in our introduction that complementarity and functionalist defences of EMT are consistent. It is just that functionalists have tended to downplay the importance of fine-grained functional differences, in a way that deprives them of important argumentative resources for mounting a defence of EMT. Erik Myin (personal communication) has however objected to us that complementarity may not be as consistent with functionalist defences of extended cognition as we think. The parity principle invites us to consider the causal contribution of an external component and imagine that this causal contribution was, contrary to fact, carried out by something in the head. If we count the causal contribution as cognitive when it is implemented by biological states inside the head, we should accord the processes making

this causal contribution the same status when they are located in the world. It is the complementarity position that biological processes located in the head don't have what it takes to make the same causal contributions to cognition as components located in the external environment. Thus the complementarity position would seem to be committed to a failure of parity of causal contribution for internal and external components of an extended cognitive system.

We agree with Myin that this is exactly what a proponent of complementarity should say about cognitive systems as they actually exist in our world. However, the parity principle is framed in terms of counterfactuals: it asks us to consider a possible world where the causal contribution of external components is made by something inside the head. Martians allow us to imagine this easily enough. We can then consider whether the internal biological components would be doing anything cognitive. If we say they would, then equality of treatment requires us to say the same when the components making this causal contribution are located in the environment. Thus we see no incompatibility between parity and complementarity either, once parity is understood as it should be, in a counterfactual way. For this reason, one might wonder whether complementarity is really a second wave in work on EMT or whether it is simply a case of uncovering something neglected but already implicit in functionalist defences of EMT.

In what remains of this paper we will make a complementarity argument for EMT based on the enmeshing and entanglement of organisms and their cognitive niches. In humans this cognitive niche is in large part cultural. We will argue that human cognition is very often the outcome of the biological and cultural resources working together over multiple timescales. We find evidence for the deep integration of the biological and cultural in work on neural development to which we now turn.

III. NEURAL PLASTICITY AND COGNITIVE DOVETAILING

Our brains begin to develop in utero at around day 25 of gestation with a remarkable 250,000 cells growing every minute [Thompson (1993)]. Each of the 100 billion neurons that make up the newborn's brain forms synaptic connections with an average of 2500 other neurons. Some of these neurons will form up to as many as 100,000 connections. Synaptic connections continue to spread until by age 2 or 3 each neuron has an average of 15,000 connections with other neurons [Eliot (1999)]. Amidst this teeming activity, how do cortical areas come to possess specific functions? According to one influential hypothesis, immature cortex is "protocortex" [O'Leary & Stanfield (1989); Quartz & Sejnowski (1997); Mareschal et al. (2007)], and functional organisation is "constructed" on the basis of experience. Brain development

is a process of progressive localisation and specialisation of function. Our brains are shaped and sculpted by the activities we repeatedly engage in, and by the environments we repeatedly encounter.

This “constructivist” view of development contrasts with the “protomap view” [Rakic (1988)] according to which the typical human brain is prespecified, and particular neurons are predestined in early development to occupy specific functions in specific cortical areas. We will argue that a constructivist account of neural development provides an important line of support for EMT. Such an account of development shows how humans could, through a process of constructive learning, come to have brains made up of structures that factor in external resources into their very functioning. It also points to a “dovetailing” of neural organisation with the external environment that supports the view we outlined in the previous section of the complementarity of inner and outer, of biological and cultural.

Consider first how neural growth itself is experience-dependent. The number of ganglion cells in the retina is decreased to 10% of normal in dark reared chimpanzees [Rasch et al. (1961)]. The number and size of cells in the lateral geniculate body, an area of the brainstem where visual information first arrives from the eye, is reduced by as much as 30-40% in monkeys deprived of visual input in their first weeks of life. Similar findings apply to olfaction: occluding the nostrils of a rat pup leads to a decrease in the size of the olfactory bulb and increased cell death [Kupfer et al. (1964)]. Hubel and Wiesel (1963) recorded electrical activity in the visual cortex of kittens that had one eye sutured closed shortly after birth and then reopened 10 days later. They found that 85% of the cells responded preferentially to the non-sutured eye, and few if any cells responded exclusively to the deprived eye. Visual input to the deprived eye didn't alter this pattern of cell sensitivity; cells responding to the nondeprived eye continued to maintain their dominance, and it was only through the occlusion of the nondeprived eye at an early age that the balance was restored.⁴

The differentiation of cortex into areas of functional specialisation seems to be equally experience-dependent. Neville and Lawson (1987) carried out an EEG study comparing the brains of congenitally deaf subjects and subjects that became deaf after the age of 4. They found significant differences in the event related potential components of the congenitally deaf subjects. They argue that early lack of auditory input in congenitally deaf infants allows for a reallocation of auditory cortex for other functions. Further support for this hypothesis comes from Braille reading studies: Sadato and colleagues (1996) used positron emission tomography (PET) to measure activation of the primary visual cortex during tactile discrimination tasks in congenitally blind Braille readers. In line with Neville and Lawson's hypothesis, the Sadato *et al.* study provides support for the idea that cortical areas are reassigned different functions when they fail to process typical inputs.

Occipital cortex is capable of reorganizing so as to support the processing of non-visual sensorimotor information.

Could the brains of typically developing adults also reorganise in this way so as to support different functions? There is compelling evidence that this is indeed possible. Pascual-Leone (2001) reports a study in which normal sighted subjects were blindfolded for five days from Monday morning to Friday evening. Subjects made their way around the hospital where the study took place using touch and hearing. During the day subjects would learn to read Braille. At the end of the study, when the brains of the participants were scanned using fMRI they found activation of visual cortex for tasks in which subjects were to discriminate the pitch of tones or detect sameness or difference of Braille symbols. After a prolonged period of sensory deprivation, the blindfolded subject's visual cortex began to take on auditory and tactile functions. When deprived of its typical inputs, visual cortex takes on new functions, and this potential isn't just confined to developing infants, but persists into adulthood.

We have just seen above how the infant brain is positively blooming with redundant connections, and these connections continue to proliferate during the first three years of an infant's life. After this age, our brains begin to undergo what is known as "synaptic pruning" in which unnecessary and redundant cell populations die off [Abitz et al. (2007); Huttenlocher (1979); Takacs & Takacs & Hamori (1994); Innocenti (1995)].⁵ Connections that are frequently and repeatedly activated are strengthened and preserved, while those that have been dormant or inactive get pruned. According to one estimate, around 20 billion synapses die off every day from childhood through to adulthood [Eliot (1999)].

The connections that are frequently used will carry traffic relating to activities in which the child regularly engages. These activities will frequently take the form of skills the child is learning from her caregivers and peers in her cultural environment. Each time the child learns to do something new, so new neural connections will be formed. As the child repeatedly engages in these activities, so the underlying neural connections will get reinforced. Synaptic pruning thus unfolds according to the "use it or lose it" principle. Those clusters of neurons that are regularly exercised stay connected, but the connections between neglected clusters gradually die out.

Synaptic pruning illustrates the experience-dependence of the brain's structural and functional organisation. The experiences that forge our brains are experiences we form by being trained in skills and socio-cultural activities many of which involve the use of cultural artefacts [Wexler (2006); Andreasen (2006); Renfrew and Malafouris (2009)]. The activities that affect the development of the brain are the work of culture. Any skilful activity we repeatedly undertake will alter our brain's structure. Brains are modified by these activities so much that we humans have what might be accurately de-

scribed as “culturally modified brains” that support plastic and adaptable minds continually absorbing new stimuli and changing as culture evolves. The neuroscientist Michael Merzenich remarks:

Our brains are vastly different, in fine detail, from the brains of our ancestors...In each stage of cultural development...the average human had to learn complex new skills and abilities that all involve massive brain change...Each one of us can actually learn an incredibly elaborate set of ancestrally developed skills and abilities in our lifetimes, in a sense generating a re-creation of this history of cultural evolution via brain plasticity [Doidge, (2007), p. 288].

We find a nice example of the importance of cultural and social activities in shaping cognitive functions in research on language acquisition [Meltzoff et al. (2009)]. Early in development, infants have the ability to distinguish all sounds across the languages of the world [Kuhl et al (1975)]. Infant’s universal capacity to perceive sounds distinctions in different languages however narrows with development. Studies in American and Japanese babies showed that by the eleventh month of age such a capacity is significantly reduced [Kuhl et al. (2006)], for instance]. It is reduced because their social context is one in which they are regularly exposed to their native language and only infrequently, if at all exposed, to other non-native languages. The reason infants gradually lose this capacity is therefore to do with their brain functions getting specialised in accordance with socio-cultural activities and specific environmental stimulation. Social interaction greatly influences infants’ learning capacity, and experiments reveal that language learning is profoundly gated by social processes [Kuhl (2007)]. This further confirms the crucial role that culture plays in shaping our cognitive functions and at the same time suggests that the onboard neural machinery comes to be dovetailed to fit with the particular socio-cultural environment in which our brains grow.

It is therefore the activities we repeatedly engage in the world that determine which neural circuits get to survive in our brains. Circuits that are often used get reinforced, while those that lie dormant are simply abandoned and their connections are pruned. Among the activities that are reinforced will be those required to skilfully use external artefacts in problem solving. The circuits that are getting reinforced and set up are ones that factor into their very functioning the use of these external artefacts. The couplings with external props reveal how deeply our neural circuits are sculpted and tailored by the tools we use, and the technologies and cultural practises we grow up with. Cortical structures are progressively elaborated in ways that are direct reflections of the intimate partnerships we enter into and cultivate with the environment from the very instant we are born. Our brains gradually learn to play a role within a unified, finely tuned and densely coupled system. They learn to treat external structures as reliable resources, that shape the kinds of

on board cognitive routines they support. These external structures become complementarity parts of their cognitive repertoire [Clark (2003), p. 87].

IV. EXTENDED COGNITION OR EXTENDED COGNITIVE SYSTEMS

Adams and Aizawa have argued that complementarity of the kind we have been defending may establish the existence of extended cognitive systems, but this result fails to provide support for the extended cognition hypothesis [Adams and Aizawa (2009), pp. 117-118; pp. 130-132]. Adams and Aizawa base their argument on the idea that not every component of a cognitive system will have the property of being cognitive. Consider an air conditioning system: the components of this system (e.g. the compressor, the evaporation coil, the condenser, the thermostat, fan etc.) are finely tuned and reciprocally interconnected via relatively simple and reliable connections. However, not every components of this system can be said to be performing the function of cooling the air [Adams and Aizawa (2009), p. 117]. The evaporation coil cools the air, the thermostat and fan do not. The same moral holds for a sound system. Not every component in a sound system produces sound: “The speakers do, but the receiver, amplifiers, volume controls, tone controls, resistors, capacitors, and wires do not”. [Adams and Aizawa (2009), p. 118]. Adams and Aizawa argue that the same principle holds for cognitive systems. A cognitive system may have among its parts, components that are located in the external environment. However it doesn’t follow that the contribution these components are making to the overall cognitive system is a cognitive contribution. Otto together with his pencil and notebook may form an extended cognitive system, but it doesn’t follow that the contributions of the pencil and the notebook to Otto’s cognising will thereby count as cognitive.

Complementarity, say Adams and Aizawa, at best establishes the existence of extended cognitive systems. It doesn’t establish extended cognition; at least it won’t if one concedes that extended cognitive systems work like air con and sound systems. Our first response is that it sounds a little odd to our ears to say that the evaporating coil is causally responsible, all on its own, for cooling the air in the house in which it is installed. Take the coil out of the larger system of which it is a part, and the house isn’t going to feel cooler. The air conditioning system is made up of components each of which performs particular operations, and when these components interact in the right way what you get is cool air. Maybe the evaporating coil is particularly crucial – it is if you like the “core realiser” of air conditioning, but it is only by working in partnership with all the other components that it can perform this function. Now we want to argue that the same is true of the external components of an extended cognitive system. The internal biological components

only work so as to accomplish cognition when they are working in partnership with the external, environmentally located components.

Of course this is still not sufficient to establish extended cognition: Adams and Aizawa will say the core realiser is inside the head of the cognitive agent, and it is only the core realiser that satisfies the mark of the cognitive. So, next we want to probe Adams and Aizawa's claim that extended cognitive systems are analogous with air conditioning systems. We think there are significant differences, which may decide the case in favour of extended cognition. The components of the air conditioning system have come to perform their distinctive functions through design, not through development and learning.⁶ Our brains, by contrast, learn to factor into their processing operations, external artefacts that have a place in our cultural practices. Through development, the sorts of functional structures and representations that are constructed in our brains are geared into working in partnership with external resources. These external resources become grafted into the workings of the internal neural circuitry so that at least some of our cognition can only be accomplished through the symbiotic partnership our brains have formed with their cultural environs. The inner only assumes the form it does, and works in the way it does because it is encultured, forged and moulded by the many different activities it repeatedly and regularly engages during the course of development. The biological internal components of an extended cognitive system have developed to work in partnership with the external, cultural components. Our minds are hybrid minds [Donald (2000)].

A natural objection one might raise at this point is that developmental arguments of the kind we've been expounding are powerless to establish synchronic, here-and-now extended cognition, as opposed to intracranial, embedded cognition of the kind Adams and Aizawa favour. Cognitive dovetailing of the kind we've been arguing for doesn't address the causal-constitution conflation charge that is often levelled against the EMT. According to this objection, EMT is guilty of mistaking a perhaps necessary causal contribution from the environment for the claim that environmentally located elements have cognitive status. Perhaps it will be conceded that we've shown the environment makes a necessary contribution to cognition, but we haven't shown that this contribution is cognitive.

Like the problem of the inputs and outputs, this is a worry that comes back time and time again for EMT. Doesn't the thought behind it rest on something like Adams and Aizawa's distinction between extended cognition and extended cognitive systems? It seems to require us to concede that an externally located component can be a part of an extended cognitive system, perhaps because of developmental considerations of the kind we've sketched above, without this component being counted as cognitive. We've attempted to address this objection above by talking about the way in which the internal biological neural processes factor into the operations they carry out, our skil-

ful interactions with the environment. Let us say a little more about this last point.

Can developmental, diachronic considerations really establish anything stronger than causal necessity? Ken Aizawa has provided a helpful (counter)example to us in pressing this point. He asks us to consider how the stomach can become adapted to processing alcohol over time in individuals that like to indulge in a nightly single malt or two. The stomach is adapted to dealing with this kind of environmental input, but we don't want to say the bottle of whisky in the drinks cabinet is a part of the person's digestive system. Aren't the examples of plasticity we gave above just like this whisky example where our brains have become adapted to dealing with environmental inputs and outputs? In what way is the whisky case disanalogous from the dovetailing examples we have given above?

Well a crucial difference can be found once we reflect on the relevant outputs. When a neural routine "factors-in" the use of some external resource in such a way as to work in partnership with that resource, the outputs of the nervous system only accomplish a cognitive task because they are environment involving. The environmentally located artefact we are skilfully employing is in a literal sense a part of the output the nervous system is producing. Not only is the artefact involved in the production of the output, but this output is also being recycled by the brain as input to its cognitive processing, in a way that Clark (2008) has described as cognitive self-stimulation. This is not the case in the digestive system example: its outputs don't include the whisky bottle in my cabinet even if the workings of my digestive system are finely tuned to dealing with whisky.

No doubt there are many more iterations of this debate to unfold in the literature on extended cognition in the near future, perhaps even in this special issue of *Teorema*. We want to end by noting that the intracranial embedded view of cognitive systems relies on an individualist conception of mind, one that we think can't be sustained in the light of the developmental evidence. It assumes that the information processing operations carried out by an individual's brain suffice to account for cognitive processes with the cultural setting providing at best non-cognitive inputs. We won't attempt any knock down arguments against individualism, but we do think that significant doubt has been cast on its plausibility by the work on neural development we've introduced above. This work provides strong support for a view of our minds as hybrid, part biological and part cultural. To the extent that developmental considerations support such a view of mind, they will also undermine individualism, and an intracranialist perspective on cognition. This doesn't directly establish here-and-now synchronic extension, but it does however call into question any intracranial alternative. Once we see how our brains are sculpted and nurtured to work in partnership with our cultural surroundings,

this substantially weakens the case for thinking of the brain of a single individual as the container of the mind.

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ACKNOWLEDGMENTS

Many thanks to John Sutton, Ken Aizawa, Erik Myin, Mark Sprevak, Andy Clark, Till Vierkant, and Olle Blomberg for their helpful comments on earlier drafts of this paper.

NOTES

¹ Sutton (2002; 2006; 2010) was probably the first to pick out the theme of complementarity as an alternative to parity based defences of EMT. The theme was however also present in Clark's (1997) *Being There* in which Clark illustrates the transformative power of artefacts, institutions, and social networks for human cognition. It is also a central theme in Rowlands (1999; 2010) and has subsequently formed the basis for Richard Menary's defence of extended cognition based on the idea of cognitive integration [Menary (2006; 2007)].

² See [Adams & Aizawa (2008)]; [Adams (2010)]; [Clark (2006), (2008), (2010a), (2010b)]; [Menary (2007), (2010)]; [Rowlands (2010)]; [Rupert (2004), (2009), (2010)]; [Sprevak (2009)]; [Sutton (2010)]; [Walter (2010)]; [Weiskopf (2010a), (2010b)]; [Wheeler (2010, (forthcoming))], to name a few.

³ Analogous arguments can be run for the other of the glue and trust conditions [see Adams and Aizawa (2008), §7.3.1; Sprevak (2009), §§5-6].

⁴ All of the studies we cite in this paragraph are taken from Bruce Wexler's review of sensory deprivation studies and their effects on neural development in chapter 2 of his excellent *Brain and Culture* [Wexler (2006)].

⁵ There is a tension here between Neuroconstructivism and Selectionism. The former takes synaptic pruning as a case study to argue for a progressive increase in the complexity of representations. This increase is realized in the brain by a progressive elaboration of functional cortical structures. The latter, on the contrary, interprets pruning as a regression in brain development and argues that cognitive structures only emerge by selection from a richer (but constrained) juvenile stock.

⁶ Olle Blomberg (personal communication) has also pointed out that the air con system is just bolted onto the room, and aside from this doesn't change the construction of the room. Humans, by contrast, have a rich culture which preserves and transmits knowledge across generations. This knowledge is used to construct the kinds of environments we grow up in and which in turn sculpt our brains. Blomberg points out to us that for this reason it makes sense to think of humans and their environments as co-constructed.

REFERENCES

- ABITZ, A. et al. (2007), "Excess of Neurons in the Human Newborn Mediodorsal Thalamus Compared with that of the Adult", *Cerebral Cortex*, vol. 17, pp. 2573-2578.
- ADAMS, F. (2010), "Why We Still Need a Mark of the Cognitive", *Cognitive Systems Research*, vol. 11, pp. 324-331, [doi:10.1016/j.cogsys.2010.03.001].
- ADAMS, A. and AIZAWA, K. (2001), "The Bounds of Cognition", *Philosophical Psychology*, vol. 14, pp. 43-64.
- (2008), *The Bounds of Cognition*, Chichester, West Sussex, Wiley-Blackwell Publishing Ltd.
- ANDREASEN, N.C. (2006), *The Creating Brain*, Chicago, Chicago University Press.
- BLOCK, N. (1978), "Troubles with Functionalism", *Minnesota Studies in the Philosophy of Science*, vol. 9, pp. 261-325.
- CHAMBERS, D., and REISBERG, D. (1985), "Can Mental Images Be Ambiguous?", *Journal of Experimental Psychology: Human Perception and Performance*, vol. 11, pp. 317-328.
- CLARK, A. (1997), *Being There: Putting Brain, Body, and World Together Again*, Cambridge, MIT Press.
- (2001a), "Reasons, Robots, and the Extended Mind", *Mind & Language*, vol. 16, pp. 121-145.
- (2001b), *Mindware: An Introduction to the Philosophy of Cognitive Science*, Oxford, Oxford University Press.
- (2003), *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence*, New York, Oxford University Press.
- (2006a), "Material Symbols", *Philosophical Psychology*, vol. 19, pp. 291-307.
- (2006b), "Language, Embodiment, and the Cognitive Niche", *Trends in Cognitive Sciences*, vol. 10, pp. 370-374.
- (2007), "Curing Cognitive Hiccups: A Defense of the Extended Mind", *The Journal of Philosophy*, vol. 106, pp. 163-192.
- (2008), *Supersizing the Mind: Embodiment, Action and Cognitive Extension*, Oxford, Oxford University Press.
- "Memento's Revenge. The Extended Mind Extended", in Menary, R. (ed.), *The Extended Mind*, Cambridge, Mass., MIT Press, pp. 43-66.
- (2010b), "Finding the Mind", *Philosophical Studies*, vol. 152, pp. 447-461.
- CLARK, A. and CHALMERS, D. (1998), "The Extended Mind", *Analysis*, vol. 58, pp. 7-19.
- DEHAENE, S. (2007), "A Few Steps Towards a Science of Mental Life", *Mind, Brain and Education*, vol. 1, pp. 28-47.

- DEHAENE, S., SPELKE, E., PINEL, P., STANESCU, R. and TSIVKIN, S. (1999), "Sources of Mathematical Thinking: Behavioral and Brain-Imaging Evidence", *Science*, vol. 284, pp. 970-974.
- DOIDGE, N. (2007), *The Brain that Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science*, New York, Penguin Books.
- DONALD, M. (2000), "The Central Role of Culture in Cognitive Evolution: a Reflection on the Myth of the Isolated Mind", in Nucci, L. (ed.), *Culture, Thought and Development*, New York, Psychology Press, pp. 19-38.
- ELIOT, L. (1999), *What's Going On In There: How the Brain and Mind Develop in the First Five Years of Life*, New York, Random House, Bantam Books.
- HAUGELAND, J. (1998), "Mind Embodied and Embedded", in Haugeland, J. (ed), *Having Thought: Essays in the Metaphysics of Mind*, Cambridge, Mass., Harvard University Press, pp. 207-223.
- HUBEL, D. H. and WIESEL, T. N. (1963), "Effects of Visual Deprivation on Morphology and Physiology of Cells in the Cat's Lateral Geniculate Body", *Journal of Neurophysiology*, vol. 26, pp. 978-993.
- HUTTENLOCHER, P.R. (1979), "Synaptic Density in Human Frontal Cortex. Development Changes and Effects of Age", *Brain Research*, vol. 163, pp. 195-205.
- INNOCENTI, G.M. (1995), "Exuberant Development of Connections and Its Possible Permissive Role in Cortical Evolution", *Trends in Neurosciences*, vol. 18, pp. 397-402.
- KUHL, P. K. (2007), "Is Speech Learning 'Gated' by the Social Brain?", *Developmental Science*, vol. 10, pp. 110-120.
- KUHL, P.K. et al. (2006), "Infants Show a Facilitation Effect for Native Language Phonetic Perception Between 6 and 12 months", *Developmental Science*, vol. 9, pp. F13-F21.
- KUHL, P.K., and MILLER, J.D. (1975), "Speech Perception by the Chinchilla: Voiced-Voiceless Distinction in Alveolar Plosive Consonants", *Science*, vol. 190, pp. 69-72.
- KUPFER, C., and PALMER, P. (1964), "Lateral Geniculate Nucleus: Histological and Cytochemical Changes Following Afferent Denervation and Visual Deprivation", *Experimental Neurology*, vol. 9, pp. 400-409.
- LYCAN, W.G. (1996), *Consciousness and Experience*, Cambridge, Mass., MIT Press.
- MARESCHAL, D., JOHNSON, M.H., SIROIS, S., SPRATLING, M.W., THOMAS, M.S.C. and WESTERMANN, G. (2007), *Neuroconstructivism: How the Brain Constructs Cognition*, Oxford, Oxford University Press.
- MELTZOFF, A., KUHL, P., MOVELLAN, J., and SEIJNOWSKI, T. (2009), "Foundations for a New Science of Learning", *Science*, vol. 325, pp. 284-288.
- MENARY, R. (2006), "Attacking the Bounds of Cognition", *Philosophical Psychology*, vol. 19, pp. 329-344.
- (2007), *Cognitive Integration: Mind and Cognition Unbounded*, New York, Palgrave Macmillan.
- (ed.) (2010), *The Extended Mind*, Cambridge, Mass., MIT Press.
- NEVILLE, H.J. and LAWSON, D. (1987), "Attention to Central and Peripheral Visual Space in a Movement Detection Task: an Event-Related Potential and Behavioral Study. I. Normal Hearing Adults", *Brain Research*, vol. 405, pp. 253-261.
- O'LEARY, D.D.M. and STANFIELD, B.B. (1989), "Selective Elimination of Axons Extended by Developing Cortical Neurons Is Dependent On Regional Locale. Experiments Utilizing Fetal Cortical Transplants", *Journal of Neuroscience*, vol. 9, pp. 2230-2246.

- PASCUAL-LEONE A. and HAMILTON R. (2001), "The Metamodal Organization of the Brain", *Progress in Brain Research*, vol. 134, pp. 427-445.
- QUARTZ, S.R., and SEJNOWSKI, T.J. (1997), "The Neural Basis of Cognitive Development: A Constructivist Manifesto", *Behavioral and Brain Sciences*, vol. 20, pp. 537-596.
- RAKIC, P. (1988), "Specification of Cerebral Cortical Areas", *Science*, vol. 241, pp. 170-176.
- RASCH, E., SWIFT, H., RIESEN, A. H. and CHOW, K. L. (1961), "Altered Structure and Composition of Retinal Cells in Dark-Reared Mammals", *Experimental Cell Research*, vol. 25, pp. 348-363.
- RENFREW, C. and MALAFOURIS, L. (2009), *The Cognitive Life of Things: Recasting Boundaries of the Mind*, Cambridge, McDonald Institute for Archaeological Research.
- ROWLANDS, M. (1999), *The Body in Mind: Understanding Cognitive Processes*, Cambridge, Cambridge University Press.
- (2010), *The New Science of The Mind: From Extended Mind to Embodied Phenomenology*, Cambridge, Mass., MIT Press.
- RUPERT, R. (2004), "Challenges to the Hypothesis of Extended Cognition", *The Journal of Philosophy*, vol. 101, pp. 389-428.
- (2010), "Extended Cognition and the Priority of Cognitive Systems", *Cognitive Systems Research*, vol. 11, pp. 343-356 [doi: 10.1016/j.cogsys.2010.04.002].
- SADATO, N., PASCUAL-LEONE, A., GRAFMAN, J., IBANEZ, V., DEIBER, M.P., DOLD, G., and HALLETT, M. (1996), "Activation of the Primary Visual Cortex By Braille Reading in Blind Subjects", *Nature*, vol. 380, pp. 526-528.
- SPREVAK, M. (2009), "Extended Cognition and Functionalism", *The Journal of Philosophy*, vol. 106, pp. 503-527.
- SPREVAK, M. (2010), "Inference to the Hypothesis of Extended Cognition", *Studies in History and Philosophy of Science*, vol. 41, pp. 353-363.
- SUTTON, J. (2002), "Porous Memory and the Cognitive Life of Things", in Tofts, D., Jonson, A. and Cavallaro, A. (ed), *Prefiguring Cyberculture: An Intellectual History*, Cambridge, Mass., MIT Press, pp. 130-141.
- (2006), "Distributed Cognition: Domains and Dimensions", *Pragmatics & Cognition*, vol. 14, pp. 235-247.
- (2010), "Exograms and Interdisciplinarity: History, the Extended mind, and the Civilizing Process", in Menary, R. (ed), *The Extended Mind*, Cambridge, Mass., MIT Press, pp.189-225.
- SUTTON, J., HARRIS, C., KEIL, P. and BARNIER, A. (2010), "The Psychology of Memory, Extended Cognition, and Socially Distributed Remembering", *Phenomenology and the Cognitive Sciences*, vol. 9, pp. 521-560 [doi: 10.1007/s11097-010-9182-y].
- TAKACS, J. and HAMORI, J.(1994), "Development Dynamics of Purkinje Cells and Dendritic Spines in Rat Cerebellar Cortex", *Journal of Neuroscience Research*, vol. 38, pp. 515-530.
- THOMPSON, R.F. (1993), *The Brain: A Neuroscience Primer*, New York, W.H. Freeman and Co.
- VAN LEEUWEN, C., VERSTIJNEN, I.M., and HEKKERT, P. (1999), "Common Unconscious Dynamics Underly Uncommon Conscious Effect: A Case Study in the

- Iterative Nature of Perception and Creation”, in Jordan, J.S. (ed.), *Modeling Consciousness Across the Disciplines*, MD, University Press of America.
- WALTER, S. (2010), “Cognitive Extension: The Parity Argument, Functionalism and the Mark of the Cognitive”, *Synthese*, vol. 177, pp. 285-300. [doi: 10.1007/s11229-010-9844-x].
- WEISKOPF, D. (2010a), “The Goldilocks Problem and Extended Cognition”, *Cognitive Systems Research*, vol. 11, pp. 313-323. [doi:10.1016/j.cogsys.2010.04.001].
- (2010b), “Review of *Cognitive Integration: Mind and Cognition Unbounded*”, *Mind*, vol. 119, pp. 515-519.
- WEXLER, B.E., (2006), *Brain and Culture: Neurobiology, Ideology and Social Change*, Cambridge, Mass., MIT Press.
- WHEELER, M. (2010), “In Defence of Extended Functionalism”, in Menary, R. (ed.), *The Extended Mind*, Cambridge, Mass., MIT Press, pp. 245-270.
- (forthcoming), *Extended X: Recarving the Biological and Cognitive Joints of Nature*, Cambridge, Mass., MIT Press.
- WILSON, R. (2004), *Boundaries of the Mind: The Individual in the Fragile sciences*, Cambridge, Cambridge University Press.