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ORIGINAL PAPER

LIS and BCIs: a Local, Pluralist, and Pragmatist Approach to 4E Cognition

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Abstract Four previous papers in this journal have discussed the role of Brain-Computer Interfaces (BCIs) in the lives of Locked-In Syndrome (LIS) patients in terms of the four "E" frameworks for cognition – extended, embedded, embodied, and enactive (also called enacted) cognition. This paper argues that in the light of more recent literature on these 4E frameworks, none of the four papers has taken quite the right approach to deciding which, if any, of the E frameworks is the best one for the job. More specifically, I argue for an approach that is pragmatist rather than purely metaphysical, pluralist rather than monist, and perhaps most importantly, local to particular research programmes, rather than about BCIs in general. The paper will outline this approach, then illustrate it with reference to a particular research programme which tackles the issue of BCI communication for patients in Complete Locked-In Syndrome (CLIS).

Keywords Locked-in syndrome · Brain-computer interfaces · Extended cognition · Enactivism · 4E cognition · Pluralism

Introduction

Four previous papers in this journal (by Andrew Fenton and Sheri Alpert [1], Sven Walter [2], Miriam Kyselo [3], and Richard Heersmink [4]) have discussed the role of Brain Computer Interfaces (BCIs) in the lives of Locked-In Syndrome (LIS) patients in terms of the four "E" approaches to cognition – extended, embedded, embodied, and enactive (or enacted) cognition.[1] Since those papers were written, the literatures on each of the E's, as well as the literature comparing them, have expanded considerably in breadth and richness. In the light of these developments, it appears that none of the previous papers took quite the right approach to their task.

In this paper, I argue for an approach based closely on the study of scientific practice, i.e. we should be concerned primarily with whether sciences making use of extended / enactive / etc. frameworks for cognition are successful. In this sense I recommend an approach that is pragmatist, rather than purely metaphysical.[2] I also argue that the best "E" framework to use varies with the task at hand, so multiple frameworks could be equally "good". In this sense the approach I recommend is pluralist, rather than monist. I also advocate making local studies of particular pieces of research, rather than talking about BCI research in general.

Although none of the previous papers have taken quite this approach, there is much of use in them that I will return to here, in particular Fenton and Alpert's notion of the extended cognition framework as a *lens*

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[1] For the "4E" terminology, see for example the *Phenomenology of Cognitive Science* special issue [5].

[2] I intend this distinction as part of the explanation of what I mean by "pragmatist". I do not intend to assume a particular account of metaphysics.

through which to see the problem (p.126) [1]. I will use this as a starting point, recommending a modified lens metaphor.

The first section of the paper will summarize the debate so far; the second will explain the ways in which the 4E literature has moved on, and how this begins to lay the foundations for a new approach; the third will flesh out the new approach in more detail; and the fourth section will sketch an illustration showing how it should work in practice. The illustration will look closely at a particular piece of BCI research, namely Andrea Kübler and Niels Birbaumer's 2008 paper 'Brain-computer interfaces and communication in paralysis: Extinction of goal directed thinking in completely paralysed patients?' [6]. This paper raises the issue of failures of BCI communication in complete locked-in syndrome (CLIS), and puts forward a possible explanation for the problem. I will suggest that Kübler and Birbaumer are here making use of the enactivist lens, but that subsequent research their paper has given rise to is making use of different lenses, and must do so in order to investigate the issue. This illustrates the value of treating each piece of research separately, with an openness to pluralism about lenses.

The Debate so Far

LIS is a rare condition caused by brain damage to the ventral pons, usually caused by a stroke or degenerative disease like Amyotrophic Lateral Sclerosis (ALS, otherwise known as motor neuron disease), but occasionally by trauma. For a good brief overview of LIS, see [7]. Patients are largely or entirely paralysed and unable to speak, but consciousness is preserved and there appears to be a high level of cognitive functioning in most cases, although testing cognitive functioning can be difficult [8, 9]. In classic LIS, patients retain vertical eye movement and/or eyelid movement, through which slow communication is possible. In CLIS, even this movement is lost, leaving patients with no means of communication. The possibility of BCI communication is important for these patients in particular.

A BCI is a device allowing brain activity to be read and translated into outcomes such as the movement of a robot arm or a cursor on a screen. Neural activity is detected by electrodes, either placed on the scalp, or implanted into the motor cortex. Various types of BCI are used, based on the detection of different kinds of brain activity. In one application for communication, the user imagines bodily movements in order to move a cursor around a virtual keyboard, for example imagining moving the right hand to move to the right and the left hand to move to the left. Letters are selected by imagining another movement, for example squeezing the hand. Words can thus be spelled out, allowing communication (p.209) [4]. This BCI exploits brain plasticity, as it 'attempts to assign to cortical neurons the role normally performed by spinal motoneurons' [10], quoted (p.122) [1].

The previous papers in this journal talk about the potential of BCIs with respect to both the *cognitive* lives and the *selves* of LIS patients.[3] Fenton and Alpert argue that BCIs can extend both of these aspects, drawing on the extended mind theory of Andy Clark and David Chalmers [11]. According to proponents of extended mind or extended cognition,[4] the physical substrate for cognitive processes is found spread over brain, body and world. For example, in using a pencil and paper to conduct a calculation, the cognitive process takes place spread over the brain, pencil, hand, and paper; the activities of writing and reading what has been written are as much part of the cognitive process as the electrical activity of neurons in the brain. According to the brainbound view that extended cognition aims to displace, only what happens in the brain is cognitive; the reading and writing are merely inputs and outputs to and from the cognitive processes (Fenton and Alpert discuss the calculation example on p.126; see also (pp.86–87) [12], (pp.237–240) [13]). Although this view is typically applied to classically cognitive processes like calculating, or memory, Fenton and Alpert claim that extending cognition will also change who patients are:

> It is a matter of Western tradition to think of the self as encased in a body that facilitates engagement with the physical or social world. From the standpoint of contemporary psychology, this view of the self is untenable. Micro changes in the

[3] It might be that these two things cannot truly be separated. Thanks to an anonymous referee for raising this issue.

[4] Here I will follow much of the post-Clark-and-Chalmers literature, and papers subsequent to Fenton and Alpert's in this journal, in referring to extended *cognition* rather than extended mind (see especially p.65, note 9 [2]). Fenton and Alpert use the terms "mind" and "cognition" apparently interchangeably in their paper, although they only speak of mind with the prefix "extended". I take it, as Walter does, that not much turns on this issue here.

> underlying neural substrate that subvenes various cognitive events reflects not just changes in the maturing biological system of which our brains are a part, but the learning that occurs as we cognitively engage with our physical or social environments. Many of these changes, particularly as they relate to learning, translate into changes in those cognitive events constituting our inner lives [14]. From our meagre beginnings as infants, our selves develop from, or emerge out of, interactions with our physical and social worlds. Our physically embodied and socially embedded nature shapes who we are [15]. With these observations in mind, we can reasonably anticipate that the relevant BCI will change who these patients are (pp.126–127) [1].

Fenton and Alpert say they wish to avoid becoming embroiled in metaphysical debates about whether the mind is extended, and instead use extended mind theory as a lens through which to see the situation of the patient-plus-BCI system, borrowing the lens metaphor from the work of Susan Sherwin [16]. They say that they use the theory 'as a lens through which we learn to re-see particular aspects of human cognitive engagement with the relevant physical or social environment', that is, they use the theory *heuristically* (p.126) [1]. I will return to the lens idea in the next two sections, as it is an important insight that, with modification, will form the basis for the approach I advocate.

Walter argues that we have not distinguished the 4E perspectives clearly enough from one another, and sets out a helpful taxonomy with definitions of each (pp.63–66) [2]. He claims to endorse the hypothesis of extended cognition (p.61); however he argues that the capacities enhanced by BCIs are all bodily, not cognitive, so BCIs are not an example of extended cognition. He suggests enactive cognition as a better framework for understanding BCIs, characterising enactive cognition as claiming that '[c]ognition is the relational process of sense-making that takes place between an autonomous system and its environment' (p.66). For Walter, this is not a question of the most appropriate lens, but of whether cognition involving a BCI *is* extended or enactive. He says, *contra* Fenton and Alpert, that extended cognition theory is inherently metaphysical, so it cannot be used merely heuristically as they attempt to do (pp.66–67). While I intend to move beyond mere heuristics here, I think Walter is too quick to dismiss the lens metaphor on these grounds, as I will explain below.

Kyselo argues against Walter that BCIs *can* be seen as vehicles of certain extended cognitive processes. According to Kyselo, Walter goes wrong in his argument that it is the *bodily*, not *cognitive*, capacities that are enhanced by a BCI. This is because 'the proponent of EXT [extended cognition] does accept that certain bodily processes count as cognitive' (p.581) [3]. Walter therefore misunderstands the theory he is analysing. When it comes to selves, Kyselo argues that enactive cognition is the right framework, because extended cognition is 'blind with respect to the subjective' and has no account of the self (pp.5–6). Elsewhere [17] Kyselo, writing with Ezequiel Di Paulo, goes further in her defence of the enactive approach. This paper claims that enactivism,[5] not extended cognition, is the best approach to LIS as a whole, i.e. for talking about cognition as well as the self.

In the final paper of the four, Heersmink claims that BCIs are not yet able to extend cognitive processes, but with technological improvements, they could do so. BCIs do not yet function in such a way that they are transparent in use, or sufficiently trusted, to count as examples of extended cognition (compare Clark and Chalmers (pp.16–17) [11]). They are not smoothly enough integrated into the cognitive lives of their users. Heersmink offers some suggestions as to how they could be improved in this respect.

In summary, the debate so far has been as follows: Fenton and Alpert have argued that BCIs can extend the cognition and selves of LIS patients; Walter has argued that cognition cannot be extended in this case because the capacities extended are bodily not cognitive, and that enactive cognition is the right framework; Kyselo has argued against him that cognition *could* be extended by a BCI after all, but that enactive cognition is the right framework to talk about the selves of LIS patients; Heersmink has given us a useful illustration of the extended cognition framework resulting in concrete recommendations for BCI design. Where does this leave us?

[5] Kyselo and Di Paulo actually defend a particular kind of enactivism (what might be called the "autopoietic enactivism" of Fransisco Varela, Evan Thompson, etc. [18, 19]). They argue that it is superior to both extended cognition, and also the sensorimotor approach of Alva Noë, which is usually construed as another variety of enactivism. I will return to sensorimotor enactivism in my case study sketch.

Fenton and Alpert introduced the lenses approach to the debate, and I think this is an important starting point. Subsequent authors have not explicitly discussed this approach, other than Walter who has argued against it. I think more attention should be paid to it, particularly in the light of more recent research into the 4E approaches.

4E Research and Lenses

All four papers in the debate so far have relied primarily on an argument for extended cognition known as the "parity principle", found in Clark and Chalmers' original paper. One of the chief things to happen in more recent literature is a move away from parity-based arguments (in the face of criticism from Robert Rupert amongst other things [20, 21]) to so-called "second wave" arguments [22] based on what John Sutton calls a "complementarity principle" [22] or on what Richard Menary calls "cognitive integration" [13].[6] A second change is increasing attempts to better distinguish extended cognition from the other "E" positions, and to work out in what respects they are compatible, and where they differ. I will explain these moves, then argue that together they pick up on important insights that should be incorporated in how we look at all four "E" approaches.

First, to illustrate the move from parity to complementarity, reconsider the example of paper and pencil calculation. A parity-based argument would compare this scenario with the same calculation done purely in the head (perhaps picturing the lines of working one might otherwise write down). The key statement of the parity principle is: 'If, as we confront some task, a part of the world functions as a process which, *were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world *is*…part of the cognitive process' (p.8) [11]. In terms of our example, if picturing the calculations you would write down would count as cognitive, then actually writing them down should too. Part of the problem with construing things this way is the issue of the level of grain at which parity should be found. While there is an important respect in which writing out the calculation and imagining it are the same process, there are also important respects in which they are different. Which of these respects is crucial formed a major part of the debate leading up to the move away from the parity principle [20, 21], [23], (pp.114–115) [12].

A second wave argument for extended cognition would point instead to the complementarity of inner and outer components (the processes in the brain, and the reading and writing), or their functional integration into a single process. According to Sutton's complementarity version of this principle, as he says,

> in extended cognitive systems, external states and processes need not mimic or replicate the formats, dynamics, or functions of inner states and processes. Rather, different components of the overall (enduring or temporary) system can play quite different roles and have different properties while coupling in collective and complementary contributions to flexible thinking and acting (p.194) [22].

Such an argument does not rely on similarities between inner and outer processes like parity arguments do, and thus does not need to identify a level of grain at which similarity should be found. Instead it focusses on how inner and outer work together as components of a single system carrying out a single overarching process. Although I will ultimately adopt a pluralist perspective with respect to the four "E's", so I do not want to defend extended cognition in particular, second wave or otherwise, I think the move to the second wave picks up on something important. The crucial thing is the move away from judging 4E frameworks by comparison with the brainbound framework to assess parity, and towards judging them by how they work for science in their own right.

The second wave approach raises the question of how we should individuate systems: Why is it that focussing on the integrated person-paper-pencil system is better than focussing on the brainbound system and treating everything else as inputs and outputs? Why should the former be classed as *functionally* integrated (to use Menary's second wave term)? The way to identify functionally integrated systems is to look at what makes for successful science when treated as such,[7] i.e. looking closely at scientific practice. In the case of our

[6] Although these ideas were present in the literature from the start, they have moved centre-stage (p.190, pp.204–205) [22].

[7] Compare the debate between Clark and Fred Adams and Ken Aizawa concerning the kinds of functions that can be the objects of fruitful scientific investigation [24], (pp.93–96) [12]. As Clark says here, 'It is, above all else, a matter of empirical discovery, not armchair speculation, whether there can be a fully fledged science of the extended mind' (p.96) [12].

example, if there are successful research programmes that treat extended systems performing calculating as functionally integrated, then extended cognition is the appropriate way to look at this research, regardless of any similarities or differences from the brainbound approach.

As well as this change from parity to complementarity, the 4E literature has attempted to better distinguish the four "E" positions from one another, and to work out the relationships between them. Each position now represents a more fully worked-out and clear framework for research.[8] As I said in the last section, Walter is well aware of this, and one of his criticisms of Fenton and Alpert is for a lack of clarity in distinguishing the different perspectives. Kyselo also writes about the distinction between two of the positions (extended and enactive) and the others' misunderstandings of them. However, none of the papers have drawn an explicitly pluralist conclusion from this recent work, as I will now argue we should.

I have already argued that we need a focus on scientific practice and how well each of the various 4E frameworks allow it to proceed. I now want to add that there is no reason to think that the same framework will be best for all research, so we should be open to pluralism. When we look at scientific research with the now-clarified 4E frameworks in mind, we should look at what a specific scientific project is trying to achieve, because different research has different aims. For example, for a neuroscientific project investigating the function of the amygdala, a brainbound approach might be more appropriate, whereas, to return to the example from earlier, for an investigation of calculation, extended cognition might be the appropriate framework. As well as pluralist, the approach therefore should also be local to particular instances of research, rather than addressing BCI research more generally.

This is also something that none of the other papers in this journal have done; they are looking at BCI research in general, instead of at particular research projects, as my local approach recommends. Walter does suggest in passing that this might be an issue:

> ENC [enactive cognition] will be vindicated to the extent that impairments in the conscious or cognitive life of LIS patients are found, and it will be undermined to the extent that no such impairments are found – provided, of course, that the studies that test the cognitive capacities take into account what ENC says about cognition. That no cognitive impairments are found in LIS patients counts against ENC only if the notion of the "cognitive" underlying the experimental tests is the same as the notion appealed to by the enactivist (p.71) [2].

He goes on to note the "offline" and "classical cognitivist" approach of a particular BCI study; however, he does not follow up this suggestion by looking for projects where the experimental tests were carried out with the same notion of the cognitive as the enactivist. Instead, he advocates looking at types of *cognition* that may be more amenable to enactivism. This is in line with what I have been calling a "purely metaphysical" orientation, and with monism – he appears to be looking for a type of cognition that *is* enactive, rather than one that should be viewed as such for particular scientific purposes.

Kyselo suggests one framework for cognition and another for the self, which is pluralist in a sense,[9] but not in a way which is local to particular pieces of BCI research as I have suggested.

Taken together, the insights of the second wave, and the development of the four "E's" as separate (although perhaps overlapping) research frameworks indicates that our approach should be pragmatist, local to particular research programmes, and open to pluralism. The seeds of this approach are already there in Fenton and Alpert's idea, borrowed from Sherwin, of using extended cognition as a lens. Sherwin uses the lens metaphor to think about how to treat different moral theories in bioethics. In her paper it is pluralist and pragmatist in much the way I am suggesting. Sherwin says of the lenses approach:

> I recommend that we think of the 'competing' theoretical options as a set of lenses available for helping to understand the complex moral dimensions of bioethics. Lenses are readily switched when we want a different 'view' of something and they may even be layered on top of one

[8] Although this is not to say that they cannot overlap – they are compatible in some respects and incompatible in others. As they continue to develop, it might be that some of the approaches are amalgamated into a single approach. This possibility does not speak against the kind of openness to pluralism I recommend.

[9] Thanks to an anonymous reviewer for suggesting this interpretation.

> another. (I carry three different sets of eyeglasses with me so that I can see things at a distance, read fine print, and function in bright sunlight or at night.) Some lenses will provide clearer perceptions of particular problems than others, but we may still gain understanding by trying on different options (as, for example, we can benefit by studying a tree through both binoculars and a microscope – which instrument provides the 'right' view will depend on our aims and needs at the time) (p.204) [16].

The approach is pluralist in that we do not assume one lens will work for every task, and pragmatist in the sense that which lens is best is not a question of the "correct" answer, but the best answer for our purposes in the project at hand.[10] My approach can therefore be put in terms of treating each "E" approach as a lens through which to view particular instances of BCI research, being open to the possibility that different lenses will be most appropriate for different research.

This is not so far from the mood in some of the later 4E literature. For example, Andy Clark says of deciding between some of the different "E" perspectives:

> We should not feel locked into some pale zero-sum game. As philosophers and as cognitive scientists, we can and should practice the art of flipping among these different perspectives, treating each as a lens apt to draw attention to certain features, regularities, and contributions while making it harder to spot others or to give them their problem-solving due (p.139) [12]. (See also p.117).[11]

It is because of passages like this that I think Walter is wrong to dismiss the lens metaphor. According to the pragmatism I advocate, the framework to use is the one that works best for the scientific research being carried out, i.e. the best lens, and there are indications in the 4E literature that this pragmatist orientation will and should become increasingly prevalent in the near future. We need to return to Fenton and Alpert's initial take on the issue, but with some important differences. What exactly these differences are, and how the approach should play out in relation to BCI use by LIS patients will be the subject of the next section. Here I will go beyond Fenton and Alpert's use of the lens metaphor merely as a means of avoiding metaphysics, by articulating a thoroughly pragmatist alternative.

Modifying the Lenses Approach

The chief difference between my approach and that taken by Fenton and Alpert is that I think we should view BCI research through the scientists' own lenses, not through ours. This accommodates the localism and pluralism discussed above.

Fenton and Alpert take extended cognition theory as it has been developed in philosophy, and use it as a lens through which to view any science concerned with BCI use by LIS patients; instead, I recommend that we look at a particular piece of research on its own terms, in the light of its own aims and investigative frameworks. Looking at the science through the scientists' own lenses means assessing the science according to its own standards of success. This method has two stages: First, a descriptive stage to look at the concept of cognition (or the concepts of particular cognitive processes such as calculation or memory) in use, in particular whether they are making use of one of the varieties of 4E concepts or brainbound. Second, there is a normative stage to assess those concepts on the science's own terms. This method takes the details of the scientific work seriously, while still leaving room for criticism.

Assessing the scientific project on its own terms respects the localism and pluralism discussed in this paper because it accepts that different frameworks might be best for different research. In [27] I defend an historical approach to assessing a concept on the science's own terms, according to which the concept should be shaped by factors that have been found to be legitimate in practice over time. This is based on the idea that what counts as a good scientific theory is something that emerges from scientific practice over time, and, as Dudley Shapere has argued, cannot be laid down by philosophy (p.6) [28]. I will not do the historical aspect of the normative project for my example in this paper due to constraints of space, so here I rely only on more widely accepted standards for success. This is not to say that these standards did not emerge from scientific practice, only that they did so a long time ago, and they are not particular to the research in question.

[10] I set aside here issues of how such a pluralist science could work in practice, but for some suggestions see [25, 26].

[11] There is no citation of Sherwin in Clark 2008, so it seems the reference to lenses is not (or at least not directly) from the same source.

There are several obvious objections to this approach that should be addressed at this stage. The first is that current sciences are not 4E sciences, so looking at them on their own (non-4E) terms is of no use; what philosophers are recommending is that they *should* be 4E sciences. The first thing to say in response is that this isn't the tone of much of the 4E literature, which claims that science already employs 4E concepts [12, 29]. The case I will look at here is relatively explicit in its endorsement of a kind of enactivism, although it doesn't use the term. However, the claim that some science already employs 4E concepts is perfectly compatible with most scientists not openly endorsing such approaches, because there is a distinction between scientists' *implicit* and *explicit* concepts. The experimental work of Karola Stotz, Paul Griffiths, and Rob Knight on scientists' concept GENE shows the importance of this distinction. When questionnaire probes are designed such that scientists have to *apply* their concept to deal with examples, variation between the concepts held by different groups is revealed that was not clear from analysing explicit definitions given by the scientists [30].[12] Therefore it may be that current sciences are implicitly 4E sciences, even where they are not explicitly so.

The second response to this objection is that we cannot anticipate in advance how science will proceed. We cannot insist that future science should use a particular framework such as extended cognition, because scientific research is far too complex a system to predict accurately. In other words, we cannot anticipate in advance whether research making use of one of the 4E concepts of cognition will be successful.[13] Whether such an approach (or any other) can succeed is for the science to figure out as their research plays out. Discovering such things is what we have science *for*; if they could be settled by a priori metaphysics, we would have no need of science. This does not mean there is no room for philosophical criticism; as I said above, there is a normative component to the project.

Another objection is that if a science only has to succeed on its own terms, we appear to be committed to a kind of "anything goes" relativism. Meeting this objection is the reason for the Shaperean line I have taken, that scientists' standards for success have been tested in practice. These standards must prove themselves in working research, and therefore must fit well with other aspects of research carried out in that discipline (for example widely endorsed methods and assumptions), and with the world as it is tested using those widely endorsed methods. To test a concept according to whether it allows successful science by the science's own standards is only to take into account the rest of the scientific framework in which the concept is embedded. The pluralist only adds that we have no reason to think there is only one framework that could be successful, so the same framework may not be appropriate for all research. This is not the same as saying that any framework could be appropriate for any research.

The method I propose then is to look closely at *particular* pieces of BCI research to see what kinds of concepts of cognition they are currently employing. The concepts can then be assessed according to whether they contribute to the research meeting its own aims, bearing in mind that different concepts may contribute best to different aims. I will illustrate this approach with a piece of research which uses the enactivist lens. I will suggest that this lens is appropriate but that subsequent research given rise to by their paper is making use of different lenses, and must do so in order to investigate the issue.

The Approach in Practice: a Case Study Sketch

In their paper [6], Kübler and Birbaumer set out to investigate whether there is a relationship between level of physical impairment, and BCI performance. They trained 35 subjects to use various kinds of BCI – slow cortical potential BCIs, sensorimotor rhythm BCIs, and P300-BCIs – with some subjects being trained in more than one kind. Seventeen of the subjects were in LIS, with ten of those in CLIS. The other subjects had varying levels of less severe impairment.

Results were categorized according to four levels of success in BCI performance:

[12] Because we are looking at particular cases of research rather than generalising to concept-use in a subdiscipline like Stotz et al. are doing, we have no need of experimental philosophy, but can instead look closely at the research in question, treating it as a case study, and examining it to see what implicit concepts of cognition are in play. I have given a more thorough defence of the case study approach as opposed to the experimental in [27].

[13] I am here following in particular Shapere's "Rejection of Anticipations of Nature" [31], but claims that we cannot know what kind of approach will work in advance of doing the science can be found in the extended cognition literature [32, 33].

1. Chance level – Control of the BCI was no better than chance would dictate.
2. Above chance – Performance was above chance level and reached statistical significance, but was not at a sufficient level to be used for communication.
3. Criterion level – Performance was at a level sufficient to be used for communication (above 70 % accuracy).
4. Independence – The BCI 'can be used in a so-called "free-mode", in which the EEG responses are used for independent communication, internet surfing, or environmental control – depending on the individual person's desires and needs' (p.2662).

A strong correlation was found between level of physical impairment and BCI performance, with performance worsening as impairment increased. However, when subjects in CLIS were removed from the data set, the correlation disappeared. Kübler and Birbaumer 'conclude that there is no continuous decrement in BCI performance with physical decline in this patient sample. Rather, there seems to be a clear-cut separation between the CLIS patients and all other groups' (p.2663).[14] It is their discussion of this result that is primarily of interest to us here, with a view to determining the kind of concept of cognition in play, and how well that concept is functioning.

In their discussion, Kübler and Birbaumer compare LIS patients to curarized rats in experiments which tested control of the autonomic nervous system (see also [35]). In the 1960's, it was shown that curarized rats can develop control of functions such as heart rate and blood pressure in response to reward by intracranial stimulation. In the 1980's, these results could not be replicated, and this.

> was attributed to the missing homeostatic effect of the reward: the reward acquires its positive outcome through the homoeostasis-restoring effects, i.e., ingestion of food restores glucostatic balance. In the curarized rat, where all bodily functions are kept artificially constant, the homeostatic function of the reward is no longer present because imbalances of the equilibrium do not occur (p.2665) [6].

This effect would make operant conditioning – based on rewarding the desired behaviour –impossible in the curarized rat. Classical conditioning – based on associating a signal with an involuntary behaviour – is not ruled out. Subsequent work showed that classical conditioning was possible in curarized rats, and I will return to this idea below.

In the artificially fed and ventilated CLIS patient, as in the chronically curarized rat, perception of the link between the desired behaviour and its result (the reward) is not strong enough for control to be developed. This is a result of both reward being too rare (training sessions fill only a small percentage of the subjects' time), and reward being blunted by the lack of homeostatic imbalances that the reward would restore in the normal subject (p.2665).

Kübler and Birbaumer conclude:

> From the failure to control autonomic functions with operant learning in the curarized rat and the studies on contingency perception and voluntary regulation and the intact cognitive event-related potentials, we may conclude that passive sensory information processing is intact in CLIS even at the most complex semantic processing levels. It is the complete lack of motor control and feedback which might be responsible for the cessation of voluntary cognitive activity, goal directed thinking and imagery supporting a "motor theory of thinking" already discussed by James (1890). A single CLIS patient who learns to communicate with a BCI or any other communication method will disprove our hypothesis. (p.2665).

The "motor theory of thinking" subscribed to here relies on interaction with the environment giving rise to cognition, and as such is a version of enactive cognition. A key concept in enactivist thought is *sensorimotor contingencies*: the way sensory inputs are contingent on movement. According to Alva Noë's sensorimotor account of perception [36], it is these contingencies that constitute our ability to perceive the world; a breakdown in these contingencies would lead to a breakdown in perception. Although the account of perception is the most thoroughly worked-out, many enactivists apply the idea to cognition in general. For example Francisco Varela, Evan Thompson and Eleanor Rosch say 'cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities' (pp.172–173) [18]. It is a breakdown in just these contingencies that Kübler and Birbaumer are pointing to

[14] This result is the opposite of that found by Piccoione et al., who did find a decline in performance as physical impairment increased [34].

in their explanation of the problem for CLIS patients learning to use a BCI.

Enactivists in philosophy are well aware of the challenge this kind of case presents, for example Noë discusses the problem of paralysis (pp.12–17) [36]. Larry Shapiro (pp.164–169) [37] distinguishes two interpretations of sensorimotor enactivism, one according to which being able to move and interact with the world is necessary at the time of cognition, and a weaker interpretation according to which it is only important that such interaction has been possible in the past. On the second interpretation, a CLIS patient would be able to use a BCI if they had started to use it before entering CLIS, so the sensorimotor dependencies could be set up. This is exactly what Kübler and Birbaumer hypothesize: 'We propose that learning BCI-control or any other contingency before onset of CLIS, which can be transferred from LIS to CLIS should prevent extinction in CLIS' (p.2665) [6].

The reference Kübler and Birbaumer make to William James also speaks in favour of their concept of cognition being an enactivist one. Anthony Chemero argues that James was a forefather of the enactivist approach, as opposed to both brainbound cognition and the other "E" perspectives which are essentially Cartesian [38, 39]. Di Paulo and Kyselo also attribute a sensorimotor enactivist concept to Kübler and Birbaumer (p.522) [17].

This concludes the descriptive part of my analysis, arguing that Kübler and Birbaumer's implicit concept of cognition is an enactivist one. The normative part must assess how well this concept is functioning. To do such an analysis justice would require a book-length treatment, and is thus beyond the scope of this paper. However, I will gesture at the kind of thing such a treatment should comprise, leading to an endorsement of the enactivist concept here, but not across the board in BCI research. This recommendation of pluralism is at least suggestive.

An important positive indication that the concept is functioning well as part of this piece of BCI research is that its use leads Kübler and Birbaumer to suggest a hypothesis for further research. I assume here that this is a relatively uncontroversial standard for success that is accepted more broadly than this piece of research, so I do not need to go into the historical justification for it discussed above. We see this standard in play when the authors say, as I quoted above, '[a] single CLIS patient who learns to communicate with a BCI or any other communication method will disprove our hypothesis' (p.2665) [6]. Providing such a testable hypothesis is a healthy sign of a science that has a future direction, in this case trying to replicate or falsify Kübler and Birbaumer's results with respect to CLIS patients. The enactivist approach also suggests training patients expected to progress to CLIS in BCI use, to see whether they can still use the BCI on reaching that state. I will return to these hypotheses, considering research that has embarked on testing them.

We can see Kübler and Birbaumer as having posed a problem – the failure of CLIS patients to learn to use a BCI – and a possible explanation – the loss of sensorimotor dependencies as seen in curarized rats. This explanation sees the problem through the enactivist lens. However, it seems there are other hypotheses which might explain the results of the paper, and using only enactivist lenses risks blinding us to these possibilities. There might be other differences between CLIS patients and others that affect their ability to learn to use a BCI. For example, there may be differences in motivation due to CLIS patients being in a state of hopelessness, or of acceptance of their state. Alternatively there may be other impairments affecting CLIS patients such that they cannot sustain the attention required to learn to operate a BCI. If it was the case that cognition would be possible for CLIS patients were it not for one of these factors, enactivism would not be the appropriate lens, because according to the enactivist framework, intact cognition is impossible for CLIS patients. This possibility cannot be directly tested for; we cannot know whether cognition *would be* possible were it not for impairments that may be always present. It is therefore possible that, even if CLIS patients do not have sufficient motivation or attention to operate a BCI, it is also impossible for them because the sensorimotor dependencies are lacking. Testing for these alternative possibilities does not therefore prove the enactivist framework wrong, but if one of these impairments is found, the enactivist explanation would become redundant. Research into these other possibilities therefore involves looking through lenses other than the enactivists'.

Worse, it seems that using only the enactivist lens would mean ceasing research into BCI use in CLIS because it is impossible on the enactivist framework. This is obviously an undesirable outcome that neither the neuroscientists nor philosophers involved in this debate should endorse or have endorsed. Switching between different lenses when appropriate is therefore

already taking place in BCI research, as I will go on to show.

Neuroscientists, including Birbaumer and his colleagues, have continued to investigate the other possibilities for explaining the CLIS problem, thus making use of different lenses for different research projects. My claim is that, as philosophers, we should take these individual research projects with their appropriate lenses on their own terms. For example, we should consider whether a particular lens is appropriate for eliminating one possible explanation for the CLIS problem using a particular experimental method, rather than whether it is appropriate for describing BCI use in LIS, or BCI use in general.

Looking through enactivist lenses, it makes sense to test whether classical conditioning is possible in CLIS patients, as it was in curarized rats. This has been done for example by Wilhelm, Jordan and Birbaumer [40] and Gallegos-Ayalla et al. [41]. We should also train LIS patients expected to transfer to CLIS in BCI use, as this would be the only way the sensorimotor dependencies could be set up. This research is ongoing, but as of 2012, none of Birbaumer et al.'s patients trained in BCI use had transferred to CLIS. They tentatively suggest a neuroprotective effect of BCI training [35].

Taking off the enactivist lenses it makes sense to look for other explanations. For example, we should look at motivation and mood in CLIS patients. This is extremely difficult to do because testing CLIS patients directly is extremely challenging. They have no means of communication, and usually cannot be brain scanned due to artificial ventilation (p.2659) [6]. However, Kübler, Birbaumer and Femke Nijboer have investigated motivational factors in ALS patients more generally [42]. They found level of impairment is not related to either depression or quality of life (p.6). However, for an individual depressed patient, they did suggest recent increased impairment as the explanation for his depression (p.5). This is in keeping with their central conclusion that 'motivational factors may be related to BCI performance in *individual subjects*' (p.1, my emphasis). It is interesting to speculate that such results might generalise to CLIS, although this must remain at the level of speculation or risk begging the question, since it is differences between CLIS subjects and others that we were looking for in the first place.

Making use of the minimal testing that is possible in CLIS, Daniele De Massari et al. [43] test attention before and after BCI sessions.[15] They found that attention did typically decline across a session, leading them to suggest.

> that the identification of a neurophysiological marker of the attention level could be employed to reduce the performance variability of patients with disorders of consciousness in the use of functional MRI or EEG-based communication paradigms leading to a potential solution for the unresponsiveness of those patients (p.1998).

They conclude by saying that options other than the 'possibility of general extinction of goal-directed thinking' (p.1999) are currently being explored. Here we see them explicitly referring to the attempt to rule out hypotheses other than the enactivist one. As I have said, this requires putting the enactivist lenses aside, at least for some research projects.

Research into CLIS is very challenging, and is still ongoing. However, the projects I have considered here illustrate why, as philosophers, we should expect to see different concepts of cognition – different lenses – in play in different research projects. As I have said, we should consider for example whether a particular lens is appropriate for eliminating one possible explanation for the CLIS problem using a particular experimental method, rather than whether it is appropriate for describing BCI in LIS, or BCI use in general. In other words, our approach should be local to particular pieces of research, focussed on the details of the practice of that research, and open to pluralism in the sense of different lenses being employed.

Conclusion

The previous section completes my brief illustration of how to apply my approach. I have argued that we see neuroscientists switching between different lenses in order to best solve particular problems, and that when looking at their work as philosophers, we should do so through their lenses. This amounts to figuring out what concept of cognition they are employing (one of the "E's", or brainbound), and whether using that concept is allowing the research to be successful. The standards

[15] It is worth noting that this test was not the main aim of their paper, and a full analysis of their concepts would involve looking more closely at how this test fits with their main aim.

for success to be used are those that have emerged from the practice of the relevant science over time.

For the particular problem of BCI use in CLIS, enactivist lenses suggest some possibilities for further research, but there are other possibilities that require taking off the enactivist lenses. We should be pluralist in order not to blind ourselves to any of these options.

My approach is in the spirit of the second wave approach to 4E cognition in its focus on scientific practice. It marks a move away from judging the 4E frameworks by comparison with the brainbound framework to assess parity, and towards looking at how they work for science in their own right. It is also in the spirit of work clarifying the different "E's". When we look at scientific research with the now-clarified 4E frameworks in mind, we should look at what a specific project is trying to achieve, because different research has different aims. This leads to an approach which is both pluralist and local to particular pieces of research, rather than about BCIs in general.

In these respects, my proposed approach goes beyond the previous papers in this journal, which were principally drawing on parity-based arguments for extended cognition. Although they are empirically informed, none of the papers look closely at particular pieces of BCI research in the way I recommend, with an openness to pluralism. Instead they draw conclusions about BCI use in LIS in general terms, which risks blinding us to the specific benefits of the different approaches for different aims.

It is the nature of the approach that considerable detail is required to do it justice. A full account of the case I have presented would need to include, for example, consideration of more criteria for successful science specific to the particular research in question. Such work might reveal different conclusions about whether the concepts in use are resulting in successful science. However, I hope the case I have made is at least suggestive. In the light of the direction 4E research is beginning to take today, there is much more work to be done.

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