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Split-brain Consciousness and the Phase Transition View

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1. Introduction

1.1 An overview

Structural changes in the brain can cause changes in consciousness. For example, damage to the V1 area can deprive one from conscious vision. Damage to the V5/MT area might also affect the content of visual consciousness: patients might become blind to smooth motion.

Commissurotomy, which prevents an epileptic seizure from being transmitted from one hemisphere to the other, might also correlate[1] with a change in consciousness. Especially, that change is in the structure of consciousness rather than the content of consciousness.

The split-brain phenomenon and the structure of consciousness have been investigated for many years. For example, Tye described the structure of consciousness from various suggested models by appealing to inference to the best explanation (Tye 2003, c.f. Bayne 2005). Among those models, three are promising candidates for split-brain consciousness: the switch model, the duality model, and the partial unity model. Each model has benefits and disadvantages. Therefore, the debate continues (among some authors) which model is the best candidate for split-brain consciousness.

My suggestion in this paper is as follows: split-brain consciousness changes among these three models diachronically. My focus is on the question whether it is possible to defend the view of diachronic transition of split-brain consciousness.

1.2 The split brain

First, I present a very brief introduction to the split-brain phenomenon. A split brain is a brain in which the nerve fibers that connect the left and right hemispheres are surgically cut. Philosophers argue that split-brain subjects often mention the following classic experiment (c.f. Sperry 1968). A split-brain subject is required to focus on the center point of a screen. This procedure ensures that the visual information from the left side of a screen is sent to the right hemisphere, while information from the right side is sent to the left hemisphere. As visual information, for example, the words "key" and "ring" are presented on each side of a screen for 100 ms. That duration is long enough for subjects to have a conscious visual experience but not long enough for the eyes to move. Not only do the words "key" and "ring" have their own meaning, but the combined word "key ring" also has its own meaning. Typically, the left hemisphere is dominant for verbal ability. Therefore, when subjects are asked to report what they saw verbally, they report that they saw the word "ring." When the same subjects are asked to choose what they saw manually with their left hand, which is governed mainly by the right hemisphere, they choose a key[2]. Subjects do not report having seen a key ring either verbally or manually.

The basic idea is as follows. If split-brain subjects cannot have a "key ring" representation (or if there is representational disunity[3]), then their consciousness is also disunified. The unity of consciousness at issue is called phenomenal unity.

1.3 Phenomenal unity

There are many notions of the unity of consciousness (c.f. Bayne and Chalmers 2003; Brook and Raymont 2010; Tye 2003, 2007). In this paper, I focus on phenomenal unity among others because it may be broken especially in the case of split-brain subjects.

We need to rely on our intuition to grasp phenomenal unity. The way to understand phenomenal unity is twofold: appealing to a subsumptive relation (top-down) or appealing to a co-conscious relation (bottom-up). Both seem to share the core idea, although they have different perspectives. Here I characterize phenomenal unity by appealing to a subsumptive relation.

There is phenomenal unity when someone entertains an experience and another experience as a whole. As an example, imagine the one given by Dainton[4] (2000, p. xiii). When I see myself snapping my finger, there are at least three kinds of conscious experiences: the tactile experience of scratching my fingers (*Et*), the visual experience of moving my fingers (*Ev*), and the auditory experience of a snap (*Ea*). It seems that we do not entertain these three experiences separately and independently. Rather, we entertain an experience as a whole (*ET*), which includes a tactile experience, a visual experience, and an auditory experience[5]. *ET*, a total conscious state, subsumes those *Et*, *Ev*, and *Ea*[6]. In other words, *Et*, *Ev*, and *Ea* are parts of *ET*.

Recently, some have insisted that our consciousness is necessarily phenomenally unified (for example, see Alter 2010; Bayne 2008, 2010; Bayne and Chalmers 2003). Bayne formulates the unity thesis as follows:

> Unity Thesis: Necessarily, for any conscious subject of experience (*S*) and any time (*t*), the simultaneous conscious states that *S* has at *t* will be sub-

sumed by a single conscious state – the subject's total conscious state. (Bayne 2010, p. 16)

In this paper, I would like to assume that the subject of experience is an organism. According to Bayne (in conversation), the Unity Thesis is biologically necessarily true[7]. Biological necessity here can be construed as a necessity by the fact of being an organism. This seems a weaker version of nomological necessity. For example, it is biologically necessary that we humans cannot intentionally stop our breath for an hour. In the same vein, it is biologically necessary that our consciousness is phenomenally unified. This thesis might turn out to be false; in other words, this view leaves it open whether a phenomenal breakdown is possible. Namely, the possibility remains that some evidence nullifies the Unity Thesis. The case of the split brain is in dispute. I pursue this problem in sections 2 and 3.

1.4 Can the right hemisphere be phenomenally conscious?

Before discussing phenomenal unity, we have to ensure that the subject at issue is fully phenomenally conscious. Especially in split-brain cases, the following issue might be raised. Normally, the left and right hemispheres have different functions. In particular, typically the right hemisphere rarely has language ability (as an exception, see Mark 1996). Such functional differences might problematize ascribing phenomenal consciousness to the right hemisphere. I examine this point very briefly.

The fact of the matter is that many authors do not regard it as a serious threat. Bayne and Schechter are aware of this problem and have briefly argued about it (Bayne 2010 Ch. 5, 9; Schechter 2012b). In a nutshell, they regard

agency as a marker of phenomenal consciousness. Behaviors generated by the right hemisphere are goal-oriented and complex enough to exclude the possibility that those behaviors are generated by unconscious "zombie systems." Therefore, they think that we can ascribe phenomenal consciousness to the right hemisphere without hesitation. In this paper, by assuming their agency marker view, I ensure the existence of phenomenal consciousness in the right hemisphere[8].

2. Split Brain and Consciousness

Thus far, various models of split-brain consciousness have been considered mainly based on third-person data[9]. Among them, three models are thought to be promising: the switch model, the (classic) duality model, and the partial unity model. My provisional conclusion in this section is that none is decisive.

2.1 The switch model

The switch model was recently proposed as a model of split-brain consciousness by Bayne (2005, 2008, 2010). Bayne seems to have obtained the basic idea mainly by reinterpreting Levy and her colleagues' 1970s experiment.

First, let us examine the original experiment (Levy et al. 1972). The experimenters presented chimeric stimuli to four split-brain subjects. A chimeric stimulus is composed of two different figures that have only a left or right half. As figures, human faces, objects that look like deer horns, line drawings of familiar objects, and a combined square and cross were chosen. Here, only figures of the same type were combined; for example, the left face of person A and the right face of person B were combined. The experimenters made the

split-brain subjects focus on the central point of the chimeric figures with a single eye, which ensured that the left half of the chimeric visual stimulus was sent to the right hemisphere, while the right half of the chimeric visual stimulus was sent to the left hemisphere. After the chimeric stimuli were presented for 150 ms, the experimenters required the subjects to point out the figure they had seen with their right hand. Then, the same procedure was done with the left hand. Finally, the experimenters required the subjects verbally report what they had seen after hiding those figures[10].

The result was almost the same for four stimuli[11]. Thus, here especially I focus on the chimeric face recognition results. When the subjects were required to choose the person's face they had seen with their left hand among several pictures, the subjects tended to choose the face whose left half had been the left part of the presented chimeric stimulus[12]. However, in the verbal reports, the subjects tended to choose the face whose right half had been the right part of the presented chimeric figure. This result was not changed if verbal reports were made first.

As an interpretation of this result, one might say that the two hemispheres had different non-chimeric representations respectively. However, if there are perfect representations in both hemispheres, then the split-brain subjects should report both representations. In other words, using pointing and verbal speech, the subjects should have reported two different figures respectively when they were asked to answer what they have seen. Nonetheless, although in fact there are cases where subjects report both figures, these cases are very rare. Or again, when one hemisphere gives an answer, it is expected that the other hemisphere have an objection to it[13]. Yet we do not have such a result.

How can we interpret this experiment? According to Bayne, his switch model explains these results best. Roughly speaking, advocates of the switch

model imply that only one hemisphere of a split-brain subject at a time can be phenomenally conscious. Namely, if the left hemisphere is conscious, then the right hemisphere becomes non-conscious, and if the right hemisphere becomes conscious, then the left hemisphere becomes non-conscious. If one hemisphere is conscious, then there is phenomenal unity as described in section 1.3. In other words, one total conscious state subsumes various experiences within that hemisphere. What is important here is that there is only one total conscious state simultaneously within an organism, for this model insists that only either the right or left hemisphere is conscious rather than two parallel streams of consciousness.

In short, this model proposes that the phenomenally conscious hemisphere switches back and forth again and again. The results of the experiment by Levy and colleagues can be explained as follows: Only one hemisphere is conscious at a time. Thus, there were no competing responses. In addition, the switch model can well accommodate other experimental results (Bayne 2010, Ch. 9).

Bayne supplements the explanation of the switch model (Bayne 2008, 2010). First, what can explain a switch of consciousness between hemispheres? In other words, by what mechanism does consciousness switch? This question can be answered by the attentional resource shared by the two hemispheres. Namely, a distributing system located in the brain stem switches consciousness.

Then, when does consciousness switch? Bayne thinks that a switch is caused by several factors. For example, the type of responses required from subjects switch consciousness. In Levy and colleagues' experiment, the verbal response and non-verbal response did not coincide. Therefore, there must be switches.

We have briefly discussed the concept of the switch model. In the next section, after the duality model is introduced, the validity of each model is exam-

ined.

2.2 Duality vs. switch

Recently, Schechter insisted that we should adopt the old-fashioned duality model rather than the new switch model as a model of split-brain consciousness (Schechter 2012a, 2013; c.f. Puccetti 1973, 1981). According to her, psychologists and neuroscientists' opinions converged on this model (Schechter 2012a; for example, see Sperry 1968). She also tries to defend this view.

The duality model (or the two-stream model) is the simplest model of split-brain consciousness. The basic idea is clear and easy to understand: If we divide the brain, then the stream of consciousness is also divided. These two phenomenal fields are not unified synchronically[14]. Recall the Unity Thesis cited in section 1.3. If there is only one subject of experience, then a conscious experience in phenomenal field L (for instance, the visual information of "ring") and a conscious experience in phenomenal field R (for instance, the visual information of "key") are not phenomenally unified. For, within that subject, there is no total conscious state that subsumes both experiences.

The duality model has two options. One is the classic duality model, and the other is the contexualist duality model. Although the classic model always assumes two streams of consciousness in the split-brain, the contextualists insist that it depends on the situation. According to the contexualists, a split-brain subject has one stream of consciousness under the normal situation, while he/she has two streams under the experimental situation (Marks 1980; Tye 2003). They insist that distinct hemispheres realize one stream under the normal situation jointly.

I would like to refute this contexualist view following Schechter (Schechter

2010), for I do not also think that it is possible for hemispheres with no direct causal interaction[15] to realize one mental token conjointly[16]. Generally speaking, to see whether multiple events conjointly realize one event, we have to examine the relationships among those multiple events. As for the mental event, we have to examine causal relationships among multiple neural events. The issue here seems to be whether relevant neural circuits are physically jointed or not. The way two neural tokens that realize a single mental token interact with each other (direct interaction) should be distinguished from the way they interact by receiving feedback from the organism's behaviors or environment (indirect interaction). For instance, when two people cooperate to draw a picture, we think that there are two distinct mental tokens there. That is because the two heads are not directly causally connected. If the neural tokens located in different heads interact in an appropriate direct causal manner, there must be one mental token. Nevertheless, the left and right hemispheres of the split brain do not interact in this way. Thus, the contexualist duality model seems less bright. Therefore, we have to explore the possibility of the classic duality model.

Why should we support the duality model instead of the switch model? What determines which one to take? It is whether each model can account for the empirical data well; specifically, whether each can explain third-person data better.

First, let us examine the friction between the two models. As we saw in section 2.1, advocates of the switch model insist that streams of consciousness switch between hemispheres. However, the duality model insists that there are always two streams of consciousness. The experiment by Levy and colleagues is explained well by the switch model, but cannot be explained well by the duality model. If the duality model wants to show its own validity, we should

search for another kind of empirical data. That is, we need data in which both hemispheres respond simultaneously and independently. Although there are other empirical data that the switch model can explain well, Schechter thinks that there are some empirical data that the switch model cannot explain well. These results are explained well by the duality model rather than the switch model. Therefore, in some respects, the duality model is a better model of split-brain consciousness.

Schechter (2012a) refers to two kinds of data. One is a behavioral competition in an ordinary situation. The other is a simultaneous response under experimental settings.

In an ordinary situation, split-brain subjects show "diagonistic dyspraxia" phenomena. For example, while one hand chooses one clothing item, the other hand chooses other clothes. In this way, sometimes hands do contradictory actions simultaneously. Split-brain subjects show hesitation or perplexity in such situations.

Certainly, this phenomenon is striking. However, it is very rare indeed, and it is seen in only a brief period after commissurotomy surgery (Lassonde and Ouimet 2010, p. 194). Still, this phenomenon occurs. And it seems difficult to explain with the switch model.

Advocates of the switch model might reply as follows. Manual responses from one side (possibly the left side) are driven by zombie systems, and only the left hemisphere is actually conscious. Still, those behaviors can be goal-oriented enough to satisfy the agency criterion. If so, we have to assign consciousness to both hemispheres simultaneously.

If one still endorses the switch model, one has to accept a compromise, which insists that in some cases both hemispheres can be conscious at the same time[17]. However, we adopted the switch model to defend the Unity Thesis. We

have to abandon the Unity Thesis if we insist that both hemisphere are conscious in the diagonistic dyspraxia state, for the conscious states of both hemispheres do not seem to be unified under such a state.

Second, some results show that even in an experimental situation there are independent and simultaneous responses. Here I focus on the experiment by Schiffer and his colleagues (1998). In this experiment, they showed that both hemispheres could have independent emotions. Two split-brain subjects were asked various questions and required to use both hands to press pegs hidden from them. Experimenters examined the scale of the emotional reactions to the questions. For example, one subject had had a traumatic experience in his youth. His left hemisphere evaluated that traumatic experience more seriously than the right hemisphere did. However, what is important here is the timing of responses by split-brain subjects. Subjects in this experiment pressed the pegs with both hands simultaneously. Schechter introduced other experiments, but they are similar in that each can be construed with dual independent consciousness.

I would like to make the argument clear regarding the empirical findings. The switch model is at a disadvantage if one has an experimental result that shows independent and simultaneous responses. These findings instead support the duality model. However, the duality model is at a disadvantage if one has an experimental result that does not show simultaneous responses while each hemisphere receives information. These findings might support the switch model.

As we saw in 2.1 and 2.2, each model has experimental results that are against them. Then, which position should we take? If there is one decisive counter-example that implies phenomenal breakdown, then we do not need to defend the switch model any longer[18]. Consequently, the more empirical find-

ings that support duality model, the fewer prospects of the switch model we have.

Meanwhile, the duality side has to explain not only that chimeric experience but also unified ordinary behavior of split-brain subjects. As for unified behavior, the idea of sharing one body might explain it (Schechter 2009, 2012b). Perhaps, the idea such as the "interpreter" in the left hemisphere by Gazzaniga (2000) or the "extended mind" is available. We do not necessarily need to appeal only to unified consciousness to explain unified behavior.

Even so, they might also be a possible way for the switch model. It seems to me that both sides are in a stalemate. In other words, the two sides are not decisive thus far.

2.3 Partial unity and its coherence

It seems that the switch model and the duality model are not conclusive yet. In addition, there is another favorable candidate. In this section, I investigate whether the partial unity model is actually possible.

The idea of partial unity is from Lockwood (1989). According to this model, split-brain consciousness is not fully phenomenally unified; it is only partially unified. Split-brain subjects entertain neither one stream of consciousness nor two streams.

What is partially unified consciousness? Usually, the unity of experiences within a phenomenal field can be transitive. If conscious experiences *E1* and *E2* are unified and *E2* and *E3* are unified, then *E1* and *E3* are also unified. The partial unity model insists that this transitivity is not necessarily guaranteed in split brains. Let us say that *E2* is an experience shared by both hemispheres. For example, it might be an itch on the skin of the neck. According to this

view, it is feasible that conscious experiences *E1* and *E2* are unified and *E2* and *E3* are unified, but *E1* and *E3* are not unified[19]. That is to say, experiences intra-hemisphere might be phenomenally unified but experiences inter-hemisphere might not always be unified. Possibly it is because the corpus callosum is cut.

This hypothesis explains the problem of the partial cut well. When a surgeon cuts the front part of the corpus callosum, experiences *E1*, *E2*, and *E3* hold the transitivity relations. However, when all parts are cut, then transitivity might fail. This model also accommodates changes in the neural systems after surgery. Experiences that lost transitivity have regained it corresponding to neural changes[20].

Nonetheless, this hypothesis has its own problems. Is partial unity possible in this world in the first place? There are three distinct objections: projectability objection, strong inconceivability objection, and weak inconceivability objection[21] (Bayne 2010 Ch. 2). I reject the projectability objection and the strong inconceivability objection following Bayne. Then I examine how to settle the weak inconceivability objection.

First, it is difficult for us to imagine partially unified consciousness. It seems quite demanding to project ourselves into the mental lives of split-brain subjects. To put it differently, imagining their mental lives from the inside is quite difficult. Although our consciousness is phenomenally unified, theirs is not. If we cannot imagine what it is like to be a split-brain subject, then there might be no what-it's-likeness of him/her. This is the projectability objection.

I would like to reject the projectability objection very briefly. There are many hard-to-imagine cases. I assume many beings exist that we cannot project ourselves into (try to imagine what it is like to be a hemineglect patient, for example). Still, this assumption does not imply the non-existence of such conscious

states. The unprojectability does not entail the absence of partial unity. Therefore, the projectability objection is not conclusive. The partial unity model is still tenable.

However, the partial unity model faces further objections (Bayne 2010). Even though we cannot imagine what it is like to be a hemineglect patient, it is conceptually conceivable. However, we can neither imagine the partially unified conscious state from the inside nor conceive it. The type of inconceivability here[22] is the same as that of the inconceivability of "circular triangle" or "uncaused event." This is the strong inconceivability objection.

To reply to this strong inconceivability objection properly, we have to show that the concept of partially unified consciousness has no inconsistency.

It seems possible; it is conceivable that transitivity fails. No doubt, we cannot know whether there are partially unified conscious states from the first-person perspective. However, we can understand it from the third-person perspective and accept it. If there is a conceptual inconsistency, we cannot even understand the partial unity model. Compare: we cannot understand the concept "circular triangle." This is because the concepts "circle" and "triangle" are conceptually inconsistent when they are combined. In contrast, we can understand the concept "partially unified consciousness" and conceive it. That is just a conscious state in which transitivity fails. If the partial unity is characterized wholly as a conscious state without full transitivity, there is no conceptual inconsistency in the partial unity model. Thus, it is not inconceivable in a strong sense. Therefore, we can reject the strong inconceivability objection.

Here comes another objection (Bayne 2010). If we find partial unity conceivable in the strong sense, it might still be weakly inconceivable. A proposition is weakly inconceivable if we cannot know whether it is true or false for the time being. An example by Bayne is an unproved mathematical proposi-

tion. Certainly, whether that proposition is true or false can be fixed once it is proved. However, we cannot know it if it is unproved. Similarly, it is suspected that the existence of a partially unified conscious state is weakly inconceivable. If so, we cannot necessarily judge whether there is a partially unified conscious state at least for now. This is what the weak inconceivability objection says.

I think the validity of the partial unity model depends rather on the actual possibility of partial unity. For it seems to me that to see a scenario is weakly inconceivable, we have to see whether it is actually possible. There might be no conceptual inconsistency in the partial unity model. Nonetheless, conceptual consistency does not necessarily guarantee its possibility in this world. In other words, the partial unity model is feasible in some possible worlds, but we do not know if it is feasible in this world yet. Its feasibility is constrained by some law of nature.

How should we do? Bayne takes a conservative view. For now, we cannot know whether phenomenal disunity happens. Then it is better for us to think that it never happens. This strategy can rescue the intuition of the Unity Thesis.

I also agree that we do not have a way of knowing the existence of a partially unified conscious state for now. However, it seems to me that the duality model is empirically adequate and therefore actually possible. Then it follows that the Unity Thesis is false. If this is right, it is not yet determined whether the partial unity hypothesis is true or false. A natural attitude toward this state of affairs is to admit both possibilities for the present.

Then, I would like to take a pragmatic viewpoint. I assume that the partial unity is possible in this world; there really is a partial unified conscious state. Based on that putative fact, in section 3, I try to defend a view that presupposes partial unity. If the partial unity hypothesis turns out to be false in some

way, I have to rebuild my own view. Still, we can regard it as progress of the theory of split-brain consciousness. Either possibility goes.

Finally, note that the partial unity model faces similar problems that the duality model faces. Their difference is a matter of degree: full disunity and partial disunity. As a consequence, the opposition between the switch side and the duality side (the partial unity side) still remains. If that is true, then the partial unity model itself cannot fully solve the puzzle of split-brain consciousness. Therefore, we have to take another comprehensive view. In the next section, I suggest the view that combines those models diachronically.

3. An Alternative?

3.1 The phase transition view

The temporary conclusion of the previous section was as follows. It seems that the switch model and the duality model each have both favorable data and unfavorable data. Thus far, we cannot tell which is decisive, although we can assume that both models are feasible. Another candidate is the partial unity model, and it could actually be possible. However, this model shares the difficulty seen in the duality model.

These issues might suggest that a single model cannot settle the problem of split-brain consciousness. Namely, a single model cannot always accommodate data under all situations including individual differences. Therefore, instead, split-brain consciousness shifts among these models diachronically. I would like to call this the phase transition view.

I define a phase as each conscious state; thus, there are at least three phases, namely, the duality phase, the switch phase and the partiality phase. There might also be conscious states in between.

The most likely is the following scenario. Normally, the duality model nicely captures split-brain consciousness. The dualists can explain ordinary unified behaviors by appealing to the shared single body. However, under some cognitively demanding situations, split-brain consciousness changes its structure, which can be best explained by the switch model. This might be a short-term transition.

In contrast, in the long run the structure of split-brain consciousness approaches the partial unity model. Increasing inter-hemispheric transmission after surgery supports this idea. For example, immediately after surgery all split-brain subjects show no left-sided responses to verbal commands (Bogen 1993, p. 355). However, this phenomenon seems to disappear as time passes. Recall also that the diagonistic dyspraxia can be observed only immediately after the surgery. This might be because gradually both hemispheres get able to share mental tokens. A slow change in the nervous system could correspond to a change in the structure of the consciousness. In addition, the phase transition view can explain not only diachronic changes in the nervous system but also individual differences[23].

What I suggest here is this possibility of transition over time. It seems to me that we do not need to explain complex phenomena of the split brain in terms of a single model.

3.2 Clarification through objections and apparent replies

There must be so many objections and questions to the phase transition view. In this section, I consider some of them and try to reply for the time being in order to clarify that view.

First, some might claim that if there is such a transition in split brains, then

a transition in normal brains can also be possible. However, our consciousness always appears as a unified whole and there seems no transition as a consequence of changes in the environment or of actions. We always entertain one stream of consciousness; it does not branch, switch, and fragment. In other words, the phase transition view regards split-brain consciousness as unstable but the normal consciousness as stable. Then what is the difference between them?

Perhaps phase transitions do not always occur. They occur under special situations. Under some experimental settings, even conscious states realized by a normal brain can change. Bayne cites a work by Milner and Dunne (Bayne 2010, p. 212; c.f. Milner and Dunne 1977). In their experiment, the result seems to show that normal subjects can experience a switch in consciousness between the hemispheres. They presented each side of the chimeric stimulus (that is midline-missing) to the right visual field and the left visual field of subjects for a short time (100 ms). The subjects failed to notice that the stimulus presented was chimeric. There remains a chance that phase transitions occur in normal subjects. Therefore, there is no essential difference between normal brains and split brains. The difference is possible transition phases.

Second, one might wonder what causes phase transitions. Related to the first problem, what differences can a cut of the corpus callosum make regarding transitions?

A cognitive load under the experimental settings might trigger such transitions. These cognitive loads will be different in proportion to the degree of inter-hemispheric informational transmission. This still is speculation, though. Further investigation is needed to clarify the condition of the transitions.

Third, some will object that the phase transition view is an ad hoc solution to the split-brain phenomenon. In other words, this view is not open to falsi-

fication. There seems no falsifiability because the phase transition view can accommodate any third-person behavioral data of split-brain subjects. We have to show what datum could falsify it in order to say that the phase transition view is true in a non-trivial manner. Can we show such data?

I reply as follows. The issue here is not whether we can present behavioral datum that cannot be explained by phase transitions. Rather, the issue is whether we can show phase transitions occur or not. As the result by Milner and Dunne implies, the structure of the consciousness can change even in normal subjects. There might also be room for transition in the split brain.

To settle the issue, an investigation of the NCCs is necessary. For now, I cannot answer this problem well, but I point out that opponents also have the burden of proof.

The fourth problem involves the mechanism. The switch model implies one neural basis that realizes consciousness; meanwhile, the duality model posits two such bases. If we assume that mechanisms that realize each conscious model are different, then phase transitions seem never to occur.

However, what is the mechanism here? It seems to me that it is just conceptually demanded and it is not specified empirically yet. Thus, there is room for the mechanisms responsible for transitions to be found a posteriori.

The fifth objection might claim that after the reconstruction of neural networks, the structure of consciousness converges on a single model. So after a convergence, there will be no transitions any more.

As I mentioned in 3.1, the most likely is that there are short-term transitions and long-term transitions. It is possible that although under the normal situation there is a convergence (no long-term transition), under the specific situation transitions remain (short-term transition). In situations with no special cognitive loads, the structure of the split-brain consciousness might converge

(possibly on the duality model or the partial unity model). That idea is compatible with the phase transition view.

4. Conclusion

I suggested the phase transition view that diachronically joints three models of phenomenal consciousness. From the perspective of parsimony, this view might not seem tempting. However, it is likely that long-term and short-term transitions occur. This is still a stipulation though; more careful empirical investigation is needed.

The most intriguing question implied by this view is on the subject of experience. There is a debate on how to define the subject of experience or the self. Although we assumed that the subject of experience is an organism in this paper, for me it is attractive to think of it as the "phenomenal self" that is strongly connected with phenomenal consciousness (Dainton and Bayne 2005; Dainton 2008; Bayne 2010, Ch. 12). However, if we define the self as such, changes in the structure of consciousness directly affect the unity of self. For example, the transition from the switch state to the duality state might make the subject split.

This concern, however, is not directed at the phase transition view itself. Rather, this is a problem each model has. For instance, if we take the duality model, one subject of experience becomes two after the surgery. That is, the duality model itself faces the fission problem of personal identity. Whichever model we use, there will be a problem of the self. However, the phase transition view has to integrate these three modes of the self diachronically coherently. This might be a difficult problem.

We have to settle what the self is before moving on. As Churchland (1986)

points out,

> Until we know *what* we are counting, we cannot begin to count—and we cannot even say with much confidence that we have *one* of whatever it is that split-brain subjects seem to have two of. (p.182)

I will argue this problem elsewhere.

Notes

1 Of course, we can make a stronger claim. However, at this moment I would like to use the notion of correlation. See Chalmers (2000).

2 The right hemisphere has an ability to understand verbal instructions.

3 In addition, there also is access disunity (Bayne 2010).

4 I knew this example from Schechter's (2013) paper.

5 Our feeling of living in one world appears in this way. As Metzinger writes metaphorically: "Our tunnel is one tunnel; there are no back alleys, side streets, or alternative routes" (Metzinger 2009, p. 27).

6 I agree with Bayne's idea that this phenomenal unity is independent from self-consciousness (c.f. Bayne 2004).

7 The strength of necessity is different among authors.

8 Sleepwalkers might be a big problem. I will argue the criterion of phenomenal consciousness and the relationship between phenomenal and access consciousness elsewhere.

9 As for other models, see Nagel (1971) and Tye (2003).

10 Generally speaking, when a half, imperfect figure is presented to one hemisphere, split-brain subjects tend to insist that they saw the non-chimeric (symmetric) figure as a whole figure, not a half figure.

11 I do not consider slight differences.

12 Sometimes subjects chose the face that composed the right half of a chimeric figure. This might reflect following elements. First, both hemispheres can control a contralateral hand. Second, there is a phenomenon called "cross-cuing." Finally, we should consider the diachronic change in neural structures that ensure communication between hemispheres via sub-cortical structures (cf. Levy et al. 1972, p. 75).

13 Each hemisphere might know the opposite's answer from sight and hearing.

14 I use the word "stream of consciousness" when I focus on the diachronic aspect of consciousness and the word "phenomenal field" when I focus on the synchronic aspect of consciousness. However, in this paper I use these words rather loosely.

15 For now, I cannot define this direct causal interaction precisely though.

16 Here I have a vehicular conception of experiences.

17 This view will be defended in section 3.

18 However, can there be such empirical findings in the first place?

19 *E1* and *E3* are realized by different hemispheres.

20 Generally, the changes in the nervous systems are a difficult matter for specifying the NCCs (Neural Correlates of Consciousness) (c.f. Chalmers 2004). It is also a problem for specifying the structure of consciousness. Nevertheless, this fact might support the view that I will defend in section 3.

21 The distinction of strong/weak conceivability is originally from James van Cleve.

22 Strong inconceivability entails weak inconceivability. I think this is in another sense strong because at any time this inconceivability holds.

23 Split-brain subjects do not necessarily show the same experimental data.

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