Phenomenal Consciousness in the Split Brain: A Layered Unity Model

Abstract:

Split-brain subjects can consciously perceive and identify two stimuli presented simultaneously but separately in opposite hemifields. Yet, they seem to lack a conscious experience of the two stimuli together, as they cannot judge whether these are the same or different. Such breakdowns in experiential or *phenomenal* unity would carry important implications for philosophical reflection on the essential properties of conscious experience, as well as for scientific theorising about consciousness' neural and functional bases. Extant models support the preserved unity of split-brain subjects as *subjects* or *agents* but nonetheless admit that their right- and left-side conscious experiences are not unified in the problem cases. Here, I offer a new model that supplies the missing phenomenal unity. Based on the construct of layers of conscious experience, my model acknowledges breakdowns in *local* experiential layers but warrants preserved unity in *global* ones. A supporting argument draws on the preserved attentional capacities of split-brain subjects. My proposal goes beyond extant research in that it focuses on the conjoint phenomenology of simultaneous right- and left-side experiences, highlights the conceptual connections of phenomenal unity to attention, and discusses the impact of specific split-brain attentional capacities on the unity of right- and left-side experiences.

Keywords:

Split-brain syndrome; Consciousness; Phenomenal unity; Attention.

1 Introduction

Split-brain subjects are patients whose corpus callosum and other commissures connecting the right and left cerebral hemispheres are surgically severed. This procedure alleviates epileptic seizures by precluding electric activity from spreading across the brain. After the surgery, subjects report feeling normal and continue normally with their everyday lives (Sperry, 1982; Pinto, Neville et al., 2017). Nonetheless, experimental conditions expose some intriguing cases in which each disconnected hemisphere appears to perceive and feel things that the other does not.[1]

[1] Some argue that experimental conditions disrupt an otherwise unified stream of consciousness (Downey 2018). However, the fact that split-brain subjects can exhibit these dissociations at all is still of significance for consciousness research.

A hallmark case is *cross-matching inability*. When two stimuli are presented simultaneously but separately to each hemisphere, by showing them in a single visual field or placing them in a single hand, split-brain subjects can consciously perceive and identify each yet cannot judge whether they are the same or different or compare them in other ways. Notably, subjects cannot tell whether a circle in the left visual field and a square in the right visual field are the same or different shapes, even after correctly identifying them (Johnson, 1984; Sergent, 1986; Fendrich and Gazzaniga, 1989; Pinto, Neville et al., 2017; see Figure 1). Since each hemisphere receives direct information from the opposite hemifield only,[2] inability to make cross-hemifield comparisons despite correct identifications suggests that split-brain conscious perception breaks down into two independent streams (Sperry, 1982; Volz and Gazzaniga, 2017; Schechter, 2018).

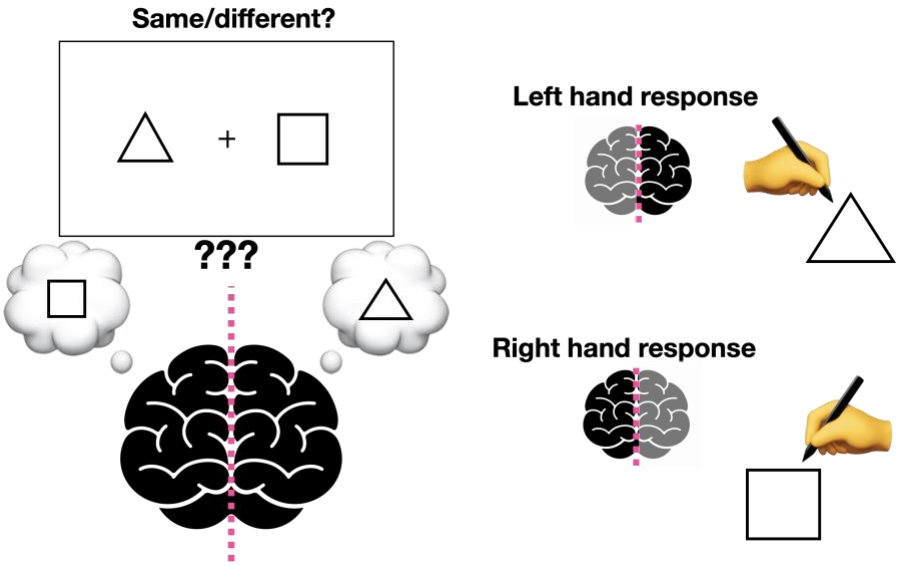

Figure 1. Cross-matching inability.

More specifically, cross-matching inability suggests that split-brain subjects lack *a conjoint conscious experience* of right- and left-side stimuli *together* –for, if they had one, they would be able to make comparisons.[3] Split-brain consciousness thus seems to exhibit a breakdown in *experiential* or *phenomenal* unity (Schechter and Bayne, 2021; Bayne, 2009), whereby subjects have a right-side experience and a left-side experience at the same time but have no conjoint experience of the two, thus:

(1) S experiences <right> at t
(2) S experiences <left> at t
(3) S does not experience <right-&-left> at t

[2] I focus on visual cases, but cross-matching inability is also observed for tactile stimuli.
[3] One could also say that subjects have the relevant experience but lack access to it. I discuss this view below.

Cross-matching inability cases thus violate a principle of synchronic phenomenal unity, according to which any two experiences of a subject at a time are phenomenally unified (Bayne, 2010). In this view, if S has experiences E1 and E2 at t, then at t S also has an experience conjoining E1 and E2. Compare: When you see the blue sky while hearing birdsong, you have an experience of blue, an experience of birdsong, and an experience of seeing blue while hearing birdsong.

Phenomenal unity is often considered an essential property of conscious experience (Watzl, 2014, 2017). Prominently, the Integrated Information Theory of consciousness (IIT) regards such claim as an axiom: an unfalsifiable truth about conscious experience (Albantakis et al., 2023; Hendren et al., 2024). If cross-matching inability cases are indeed phenomenal unity breakdowns, then we must revise our intuitions and theories of consciousness. Interestingly, IIT predicts that consciousness shall split in cases of cortical interhemispheric disconnection, since every independent hemisphere would then be more informationally integrated within itself than the two with each other (Tononi and Koch, 2015: 10).[4] More generally, split-brain breakdowns in phenomenal unity shall also confirm other theories holding that the neural mechanisms of phenomenal consciousness involve large-scale integration across the cortex (e.g., Global Neuronal Workspace Theory; Dehaene, 2014: 209), potentially falsifying theories that place these mechanisms in more local areas (e.g., Recurrent Processing Theory; Lamme, 2006; Volz and Gazzaniga, 2017).

Existing models of conscious unity in the split-brain secure agential or subject-based unity, but nonetheless admit phenomenal unity breakdowns. The *unified agency model* (Pinto, Neville et al., 2017; Pinto, de Haan et al., 2017; see also Sergent, 1986) proposes that split-brain consciousness is unified insofar as the two hemispheres inform the actions of a single conscious agent. The *switch model* (Bayne, 2008; 2010) proposes that split-brain consciousness remains one single conscious stream, whose *contents* alternate from side to side. None of these models explains how simultaneous right- and left-side experiences could have a joint phenomenology. The switch model outright denies that the subject has these experiences at the same time, while the unified agency model claims that split-brain *perception* is disintegrated into two independent streams, and even refers to this as "split phenomenality" (Pinto, Neville et al., 2017: 1236).

Here, my aim is to show how split-brain consciousness could still be phenomenally unified even in cross-matching inability and alike cases. I start by motivating *a conjoint phenomenology thesis*: a claim that right- and left-side experiences do have a conjoint phenomenology even in problem cases (Section 2). Building on this claim, I articulate *a*

[4] Though this could look like a tension between IIT's axioms and its empirical predictions, the idea is that split-brain consciousness breaks down *by splitting into two perfectly unified streams of consciousness*. Hence, the axiom of integration still holds true for split-brain subjects.

layered unity model: a model that distinguishes global and local *layers* of conscious experience, and that attributes cross-matching inability to breakdowns in the latter which nonetheless do not compromise the former (Section 3). In support of this model, I offer *an argument from attention* (Section 4). This is another novel aspect of my proposal: Though other defenders of conscious unity invoke the preserved unity of attention as an important factor for the preserved unity of consciousness in the split brain (Bayne, 2008; Pinto, de Haan et al., 2017), no discussion of how the different split-brain attentional capacities impact phenomenal unity has so far been offered. Moreover, the conceptual connections between attention and *phenomenal* unity have not yet been explicitly acknowledged within the split-brain literature. I conclude (Section 5) by discussing some implications of my proposal for our general views about consciousness, with especial focus on IIT.

2 A conjoint phenomenology thesis

Despite what cross-matching inability suggests, several findings evince that conscious perception is not completely disconnected across the split-brain hemispheres. This is initial reason for believing that right- and left-side experiences might have some kind of conjoint phenomenology.

Recently, Pinto and colleagues found that another classic hallmark of split-brain disintegration, namely, cross-response inability, does not occur in all subjects (Pinto, Neville et al., 2017; de Haan, Fabri et al., 2020). Unlike subjects in classic experiments (e.g. Gazzaniga et al., 1965), who could only report stimuli with the same-side hand, Pinto et al.' subjects could report stimuli in either hemifield using either hand *or verbally*.[5] Pinto and colleagues hypothesize that the earlier experiments might have tested subjects too soon after their surgeries (Pinto, Neville et al., 2017: 1236), suggesting that something like a split consciousness might be a transient phenomenon that gets resolved over time and does not generalise to all subjects in all conditions.

These results certainly throw new light onto split-brain cases. For example, the fact that Pinto et al.'s subjects could use either hand or verbal reports to refer to stimuli in either side suggests that split-brain consciousness is unified in the agentive sense, so that information from both hemispheres informs the actions of a single conscious agent.[6] This evidence may also suggest that right and left experiences have some conjoint phenomenology after all. Notably, however, Pinto et al.'s subjects still exhibited cross-

[5] In classic experiments, verbal reports were only obtained for stimuli in the right hemifield, as the typical host of spoken language is the left hemisphere. Sometimes, subjects even denied having seen left-hemifield stimuli (e.g., Sperry, 1968).

[6] An alternative interpretation is that unified behavior is due to cross-cueing or duplicate representations (Volz and Gazzaniga, 2017; Schechter and Bayne, 2021). I say more about duplicate representations below.

matching inability. Hence, the posited conjoint phenomenology is probably not very detailed or precise.[7]

Now, there is good number of tasks that split-brain subjects can perform, which plausibly involve comparison and integration of information across hemifields. These include comparing average size of a group of elements (Corballis, 1995; Pinto, de Haan et al., 2017), judging whether segments or arrows are aligned or assessing the size of their angle (Sergent, 1987; Corballis and Trudel, 1993; Corballis 1994, 1995), discriminating whether two successive flashes appear to move right-to-left or left-to-right, discriminating apparent motion from mere temporal succession, and discriminating successive from simultaneous flashes (Ramachandran et al., 1986; Naikar and Corballis, 1996; Naikar, 1996; see also Corballis et al., 2004). See Figure 2.

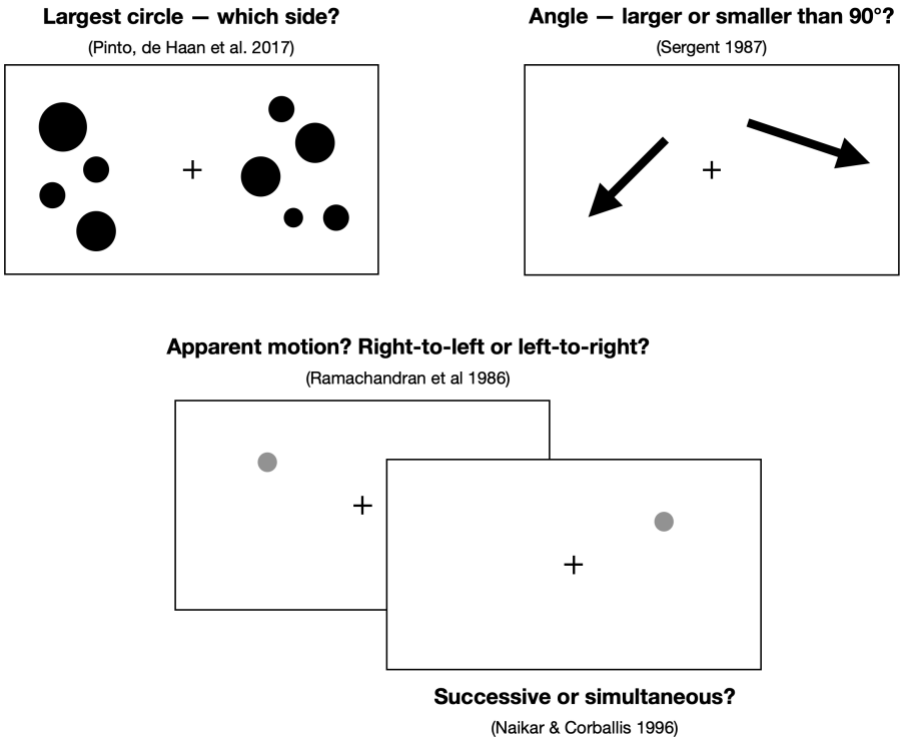

Figure 2. Cross-hemifield comparisons available to split-brain subjects.

[7] Pinto, de Haan et al. (2017: 846) argue that cross-matching might become possible with conscious effort and a considerable delay between the stimuli. Relatedly, Tramo et al. (1995) found some limited cross-matching ability when the stimuli were presented for full 5 seconds (standard presentation time is 200ms). However, these findings might not support the conjoint phenomenology claim I am pushing here. A delay between stimuli would rule out their *synchronic* unity. In turn, Tramo et al.'s stimuli were very close to the midline, a region overlapping both visual fields. Thus, unity in these cases is not unity between pairs of experiences in *opposite* hemifields.

This performance suggest that each hemisphere might have some information about what is happening in the opposite side, at least in terms of some base spatial and temporal stimulus properties. Importantly, the cited tasks can be performed even with coarse information, low in detail and spatial resolution, and do not require very detailed information about individual objects. In none of the cited paradigms can subjects recover specific stimulus properties. For example, when they discriminate the direction of motion of two successive coloured lights, they cannot report the first light's colour (Naikar, 1996). Or, while a spatial cue in one hemifield effectively directs eye movements to the equivalent location in the other hemifield, subjects cannot specify the cue's shape (Holtzman, 1984).

Information transferred across hemispheres seems to be not only coarse, but also sparse: likely under one bit, the equivalent of an answer to a Yes/No question (Schechter & Bayne, 2021; Schechter, 2018).[8] Notably, Schechter and Bayne (2021) emphasize that such limited quantity of information is insufficient to afford a unified perceptual experience across hemifields, as perceptual experiences typically have rich and specific contents and this plausibly involves lots of information. Schechter and Bayne then propose that shared information is more likely *motoric* than perceptual or semantic, so that this informational transfer might likely grant *agent* unity but probably not *phenomenal* unity.

Still, limited amounts of shared low-resolution information might suffice to support a shared percept of some general aspects of what is going on in each hemifield. There is indeed evidence that both hemispheres have information about the *presence* of stimuli in both sides, though stimuli in the opposite hemifield are sometimes described as 'shadowy' and 'too rapid to see' (Baynes et al., 1995: 1228). Thus, our available evidence affords believing the following:

> **Conjoint Phenomenology Thesis***:*
> For pairs of simultaneous but isolated right- and left-side experiences RE and LE of split-brain subject S, there is something it is like for S to experience *some (but not all) aspects* of RE and LE together.

This Conjoint Phenomenology Thesis is the minimal claim of my recommended layered unity model. Though the upcoming claims about layers of unity depend on this thesis, the converse does not hold. My claims about layers of unity are intended as a specification of what the posited conjoined phenomenology is plausibly like, but alternative specifications

[8] Milner et al. (1993) suggest that the key limitation is the quantity of transferred information, rather than its quality (e.g., resolution or level of processing). However, this position focuses on post-perceptual information transfer (i.e., what is transferred it the outcome of a Yes/No decision about the percepts; see Corballis, 1995: 942).

are possible. Still, I shall argue in the next section that global and local layers of conscious experience are the best way to make sense of the evidence.

3 A layered unity model

I have argued that, from the cross-hemifield tasks that are available to split-brain subjects, we can infer that some information is available across hemispheres. I also suggested that, if some information is available across hemispheres, this could be a plausible basis for inferring a conjoint phenomenology across right- and left-side experiences. I will now argue that, from the *kind of information* available across hemispheres, we can make an inference to the *kind of conjoint phenomenology* across right- and left-side experiences. Figure 3 summarizes the dialectics.

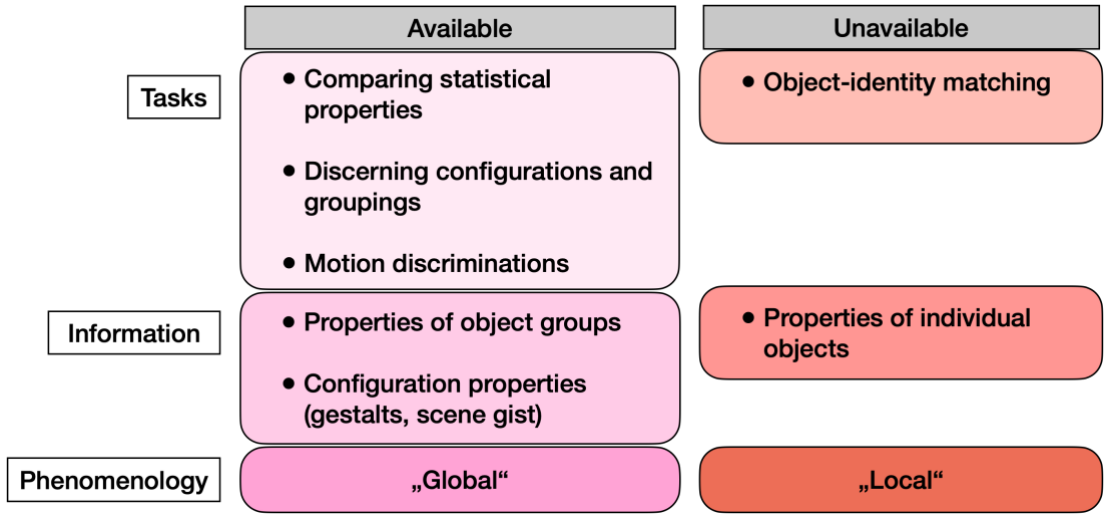

Figure 3. Tasks, information and phenomenology across hemispheres.

As Figure 3 illustrates, the main contrast between available and unavailable tasks is that these depend, respectively, on the processing of "global" vs. "local" properties, that is, properties of groups of objects and/or scene configurations vs. properties of individual objects (Prettyman, 2023). Hence, shared phenomenology across the hemifields is plausibly "global" in the described sense, while non-shared phenomenology is "local" in the described sense. Accordingly, a plausible specification of the Conjoint Phenomenology Thesis is:

Global Unity with Local Disunity:
For pairs of simultaneous but isolated right- and left-side experiences RE and LE of split-brain subject S, there is something it is like for S to experience *the global (but not the local) aspects* of RE and LE together.

Global Unity with Local Disunity captures the key proposal of the layered unity model. It states that the *global* aspects of right- and left-side experiences are phenomenally unified, even if their *local* aspects are not. The local aspects of experience are those experiential qualities associated with individual object properties, such as shapes, colours, or object categories. Split-brain subjects probably do not enjoy a conjoint phenomenology of these local aspects of their right- and left-side experiences; at least, we lack positive evidence that they do. In turn, the *global* aspects of experience are those experiential qualities associated with properties of object groups or configurations, such as occupied locations, summary statistics, or scene gist. My proposal is that split-brain subjects *do* enjoy a conjoint phenomenology of these global aspects of their right- and left-side experiences.

In a way, the construct of experiential layers is an optional add-on to Global Unity with Local Disunity. But I do take it to be a useful conceptualisation of the notion that experiences have local and global aspects. With the help of this construct, I formulate my recommended model thus:

Layered Unity Model:
In pairs of simultaneous but isolated right- and left-side experiences of split-brain subjects,
(i) *local layers* are not phenomenally unified, but
(ii) *global layers* are phenomenally unified.

If the layered unity model is an appropriate description of cases like cross-matching inability, then these cases need not violate phenomenal unity. Before, we noted that such violations arise from the following:

(1) S experiences <right> at t
(2) S experiences <left> at t
(3) S does not experience <right-&-left> at t

But if the layered unity model is correct, then (3) is strictly speaking false. According to the model, the following hold instead:

(3a) S does not experience $\text{<right-\&-left>}_{\text{LOCAL}}$ at t
(3b) S experiences $\text{<right-\&-left>}_{\text{GLOBAL}}$ at t

(3b) secures that there is no violation of phenomenal unity even in the face of (3a). Admittedly, though, one might worry that the problem will just reappears at the local layer. For if we substitute (3) with (3a) and (3b), then we should also substitute (1) and (2) for:

(1a) S experiences <right>$_{\text{LOCAL}}$ at t
(1b) S experiences <right>$_{\text{GLOBAL}}$ at t
(2a) S experiences <left>$_{\text{LOCAL}}$ at t
(2b) S experiences <left>$_{\text{GLOBAL}}$ at t

The conjunction of (1a), (2a) and (3a) can constitute a violation of phenomenal unity on its own. The point is well taken. Indeed, *some* breakdowns of synchronic phenomenal unity are, to my lights, inevitable –unless one is prepared to admit inaccessible conjoint phenomenology, but as I argue below, I do not think that this is a promising avenue. Still, by conceptualizing these breakdowns as *local*, the layered unity model allows phenomenal unity to hold globally, amongst what I call the global aspects of experience. In this way, the layered unity model explains how right- and left-side experiences could have a conjoint phenomenology despite localized breakdowns and offers a specific account of what that conjoint phenomenology is. This is, I think, as far as we can go towards securing the phenomenal unity of split-brain consciousness.

By positing global unity, the layered unity model provides a plausible conceptualisation of some recurrent ideas amongst psychologists and neuroscientists. Prominently, Trevarthen and Sperry (1973) argue that commissurotomy leaves intact a subcortically based system for *ambient vision*, concerned more with the space at large around the body than with object-identification, and more sensitive in the visual periphery than at the fovea. Similarly, Ramachandran et al. (1986) attribute split-brain subjects' ability to discern motion across the midline to an evolutionarily older "second visual system", which relies on subcortical connections with the superior colliculus and the pulvinar nucleus of the thalamus.[9] Corballis (1995: 956) characterizes this system as having "a more global reach" and a role in attracting attention to events away from fixation, thus monitoring "the big picture".

The layered unity model also aligns nicely with novel approaches to consciousness theorisation that distinguish *two levels of phenomenal consciousness*, based on cortical

[9] The superior colliculus has also been linked to Trevarthen and Sperry's ambient unity. Along with the pulvinar, this structure is implicated in the attentional functions discussed below, especially orienting and executive control (see Petersen and Posner, 2012). Schechter (2018) notes that it is unclear whether the superior colliculus affords *visual* rather than visuomotor or visuo-attentional integration. In my proposed view, if this integration is attentional then it is also visual. Another point of unclarity is whether the superior colliculus operates by transferring information between hemispheres or rather by relaying information from the eyes into the hemispheres (see Savazzi et al. 2007). The latter might, but need not, support a two-stream view –to the extent that it might enable the hemispheres to have their own representations of the visual space. I discuss an akin view towards the end of this section.

and subcortical structures (Newen and Montemayor, 2023). Layers of unity could also provide an alternative interpretation of a point from Bayne (2008: 299), namely, that split-brain surgery likely disrupts the mechanisms of conscious *contents* but not the mechanisms of *consciousness itself*, as the former are likely cortical while the latter could be subcortical. Instead of thus distinguishing between consciousness and its contents, my proposal distinguishes between layers of consciousness itself.

The layered unity model could also be combined with extant subject- or agent-unity models. The switch model's claim that the contents of consciousness inadvertently switch from side to side could be better understood as a claim about the *detailed* contents in the local layer, while global properties from both sides remain stable in experience.[10] This could explain why subjects are not aware of the proposed switches. In turn, a conjoint phenomenology for the global aspects of right- and left-side experiences could be part of the reason why one can say that split-brain subjects remain unified agents, as per the unified agency model –indeed, it seems hard to maintain such agentive unity if perception is completely disintegrated.

In these ways, the layered unity model is a plausible way to afford phenomenal unity to split-brain consciousness. Undoubtedly, many details of the proposal must be further worked-out. In the remainder of this section, I will briefly consider three immediately pressing issues.

First, there is a question about conjoint phenomenology versus *access* to conjoint phenomenology. The layered unity model countenances the following:

(3a) S does not experience <right-&-left>$_{\text{LOCAL}}$ at t

However, why not instead say:

(3a*) S experiences <right-&-left>$_{\text{LOCAL}}$ at t but *lacks access* to <right-&-left>$_{\text{LOCAL}}$ at t

In principle, one could say something like this about split-brain phenomenal unity *without even having to mention experiential layers*. The proposed picture would be:

(1*) S experiences <right> and has access to <right> at t
(2*) S experiences <left> and has access to <left> at t
(3*) S experiences <right-&-left> at t but lacks access to <right-&-left> at t

[10] This idea aligns with the way Bayne thinks of his model (Bayne 2010: 214). He proposes that while right and left contents cannot be simultaneously in the *focus* of attention, a non-focal and more *diffuse* form of attention could simultaneously spread over both sides.

In response: One immediate reason not to go with (1*)–(3*) is that inaccessible phenomenology is very contentious. Though in some cases there is some prima facie evidence for phenomenology without access, in cross-matching inability there is none. Furthermore, (3*) seems false in that split-brain subjects do have some conscious access to relevant properties of right- and left-side experience conjunctions, as evinced by the findings discussed above. Thus, the better way to make a case for inaccessible conjoint phenomenology is (3a*) or some analogous claim that clarifies what specific aspects of right- and left-side experiences are inaccessible. Such claim might be possible, and to some it might be a preferrable way to secure phenomenal unity. I shall leave that possibility open.

The second issue concerns the possibility of duplicate experiences. My conjoint phenomenology claim hinges on the idea that the hemispheres share information about the global aspects of right- and left-side experiences, so that:

(3b) S experiences <right-&-left>$_{GLOBAL}$ at t

But here, too, an alternative interpretation is possible. Instead of being shared across hemispheres, global information could be *duplicated*. That is, each hemisphere could have its own representation of global-property instantiations, for instance by directly extracting global stimulus information from the entire perceptual field. If so, then (3b) is false, for there is no genuinely *shared* phenomenology across hemispheres. Figure 4 illustrates this idea.

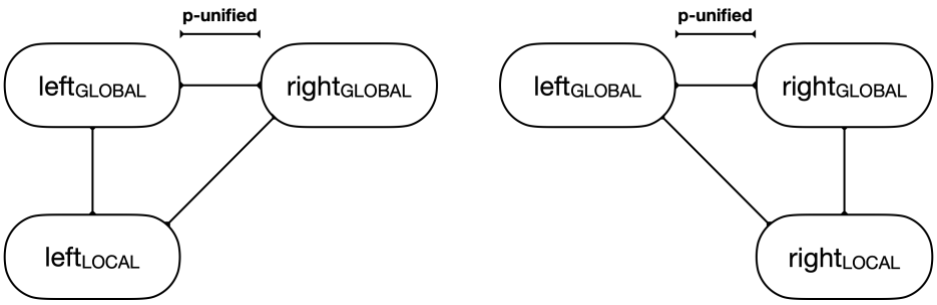

Figure 4. Duplicated experiences.

Here, too, my answer shall be tentative, as the possibility of duplicate representations should ultimately be confirmed or ruled out empirically, depending on where the mechanisms of conscious experience are based. On the two-level view I am inclined to adopt (Newen and Montemayor, 2023), subcortical structures are the likely seat for global experiential layers. If this turns out to be the right picture, it shall weight in favour of conjoint phenomenology as opposed to duplicate experiences.

The duplicate experiences view could perhaps claim a conceptual advantage: It preserves the *transitivity* of the phenomenal unity relation. Phenomenal unity is transitive if any two experiences that are unified with a third are also unified with each other; the duplicated experiences view guarantees this by positing two separate sets of experiences where every experience is unified with every other. By contrast, the layered unity model makes phenomenal unity non-transitive: Global right and left experiential layers are unified with each other, and they are also unified with the local experiential layers in their own side, but local experiential layers are not unified with each other. [11] See Figure 5.

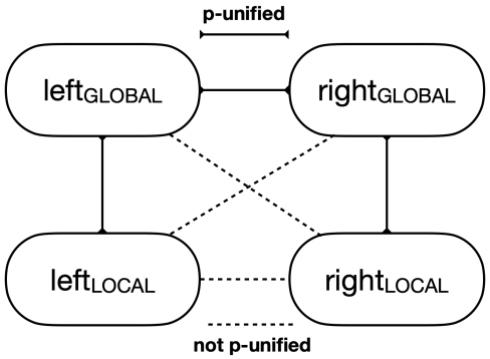

Figure 5. A transitivity breakdown

This abandonment of transitivity is the third pressing issue for the layered unity model, as one might claim that, because of it, the afforded unity is at best *partial*, and at worst not unity at all –for unity ought to be all-or-nothing and is destroyed by even a little bit of disunity. Note that the issue is not just verbal: Partial unity might appear to be a very different property from "regular", "full" phenomenal unity. For one thing, it seems very hard to imagine what having such experiences is like. Hence, ascribing this sort of unity to split-brain consciousness does not ascribe it the property we are interested in.

In response: As Schechter (2014) compellingly argues, partial phenomenal unity need not be conceptually incoherent. We might have trouble imaginatively occupying this kind of perspective, but this is not conceptual impossibility. Also, even if partial phenomenal unity is a different property from "full" phenomenal unity, it is still a relevantly similar property at least in this respect: From the point of view of the experiencing subject, their experience appears to be the way it was before the surgery (as evinced by their own reports of "feeling normal").

[11] I thank Elizabeth Schechter for bringing my attention to this point.

Finally, note that preserving the transitivity of the phenomenal unity relation in the split brain need not amount to preserving the phenomenal unity of split-brain consciousness in the sense at stake. Case in point, the duplicated experiences model: Though this view preserves transitivity in each of the two totally unified streams, the fact that there are two streams where there used to be one clearly indicates that the subject's consciousness is no longer unified in the same way it was before the surgery. Moreover, this sits uncomfortably with how split-brain subjects report as feeling normal.[12]

I will now offer an argument that shall help tipping the scales in favour of the layered unity model.

4 An argument from attention

I shall now offer an argument for the idea that right- and left-side split-brain experiences are phenomenally unified in some respects (or layers) but not in others. This argument is based on the idea that phenomenal unity constitutively depends on attention (Watzl, 2014; 2017), or is plausibly generated by attention (Wiese, 2022). If these views are correct, then attention is a sufficient condition for phenomenal unity, and we can argue as follows:

P1. If split-brain *attention* is unified, then split-brain consciousness is *phenomenally* unified.
P2. Some attentional capacities in the split brain are unified.
Therefore,
C. Split-brain consciousness is phenomenally unified –to some extent.

In support of P1: Proponents and opponents of conscious unity in the split brain often claim or implicitly assume that this unity goes hand in hand with the unity of attention (Pinto, de Haan et al., 2017: 84; Bayne, 2008: 296); to this extent, P1 is a legitimate starting point. To be sure, the unity of attention is widely claimed to be key for *conscious* unity *tout court*, rather than to phenomenal unity specifically. This is where Watzl and Wiese's arguments come in. Though here I cannot make justice to the full details of these arguments, I hope that the following key points bring the main idea across.

Watzl (2014, 2017) argues that phenomenally conscious experiences constitutively involve structures of experienced centrality, where some experiential parts are felt as *more central* or *more peripheral* from the point of view of the experiencing subject. These structures are determined by how attention is distributed over the field of experience: Things one pays attention to appear to be more central in experience, while things one does not pay attention to appear to be more peripheral. The proposal is that two

[12] See Schechter (2018) for compelling arguments for a two-thinkers view.

experiential parts are phenomenally unified insofar as they both belong to one such centrality system, where they are connected to each other by experienced centrality relations. In turn, Wiese (2022) argues that attention generates phenomenal unity by means of *attentional agency*: When a subject consciously and voluntarily decides to move her attention from an experiential part to another experiential part she was not previously attending to, she creates an experienced connection between the two experiences. Watzl and Wiese's views thus provide two attention-based sufficient conditions for phenomenal unity. Applied to present purposes, this gives us:

Attention-Based Phenomenal Unity
For pairs of right- and left-side experiences RE and LE of a split-brain subject S:

- If RE and LE are in a single centrality structure, or
- S can consciously and voluntarily decide to move her attention from RE to LE,

then RE and LE are phenomenally unified.

Attention-Based Phenomenal Unity makes P1 plausible, by providing plausible ways how attention could afford phenomenal unity. These unity-making relations are also good tools for assessing the empirical evidence for P2, in terms of how well the preserved attentional capacities can ground the unity-making relations.

Many theorists claim that *attention* remains *largely unified* in the split brain (Gazzaniga, 1987; de Haan, Corballis and Hillyard, 2020). Furthermore, studies with acallosal subjects (born without a corpus callosum) suggest that attentional unity does not depend on cortical interhemispheric connections, as attention seems equally *unified* in acallosals and neurotypical controls (Dell'Acqua et al., 2005).[13] However, other experimental work suggests a more nuanced picture.

According to Posner and Petersen's seminal taxonomy (Petersen and Posner, 2012), the attentional system in humans and other primates has three primary components, subserving *alerting*, *orienting* (which can be *top-down*/endogenous or bottom-up/*exogenous*) and *executive control* functions.[14] This gives us four main attentional capacities. Each of these exhibits different amounts of breakdown in the split brain. See Figure 6.

[13] However, Hines et al. (2002) show evidence that acallosal subjects do have difficulties with interhemispheric shifts of attention.
[14] According to some, executive control subdivides into functions for transient task control and task-set maintenance (Petersen and Posner, 2012). I leave this division out since these functions are not separately explored in split-brain research.

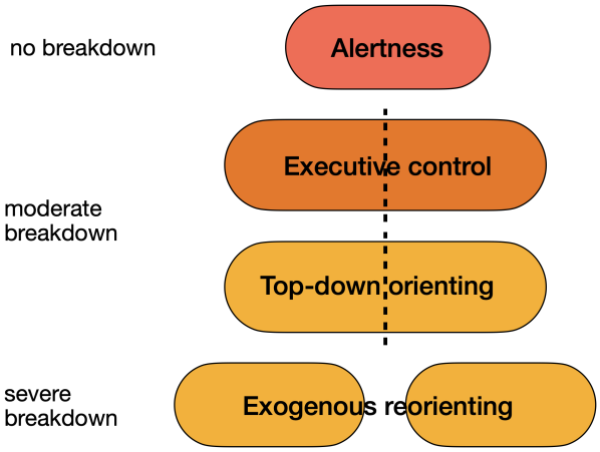

Figure 6. Attentional breakdowns in the split brain

"No breakdown" means that a function continues working just as it does in the non-split brain, so that to this extent it can be considered unified. This is the case for alertness, a function concerning a generalized state of arousal and preparedness to respond, also called *vigilance*. Though split-brain studies show that vigilance mechanisms are strongly lateralized to the right hemisphere (Dimond, 1979; Làdavas et al., 1994), this asymmetry is not a breakdown. Right-hemisphere alertness lateralization also occurs in the non-split brain (Petersen and Posner, 2012), though, like other processing asymmetries, it only comes to light in the split brain. Furthermore, there is no independent evidence of split arousal states in split-brain subjects. An extreme example of such a breakdown would be that one hemisphere sleeps while the other is alert and awake.[15] Split-brain subjects do not exhibit these patterns: Their two hemispheres typically sleep and wake up at the same time.[16] Though EEG recordings show that slow sleep waves remain confined to the hemisphere where they originated, so that there might be differences in sleep depth across hemispheres, the evidence does not support unihemispheric sleep (Avvenuti et al., 2020: 5600).

The opposite situation occurs for exogenous reorienting, the capacity to involuntarily or automatically reorient attention in response to salient external stimuli –also conceptualised as bottom-up attentional capture (Corbetta and Shulman, 2002). Several findings evince a severe breakdown in this function, which means that it appears to split into two separate and roughly independent systems. Prominently, split-brain subjects can take advantage of two simultaneous exogenous cues in opposite hemifields, while for non-split subjects two simultaneous cues are operationally equivalent to no cue and no processing advantage (Mangun et al., 1994; see Figure 7, left). They can also find a target

[15] Unihemispheric sleep is observed in some non-human animals, including dolphins, seals and chickens (Mascetti, 2016). Interestingly, many of these animals have small or absent corpora callosa, and in some it is believed that right and left visual fields are not integrated (e.g., corvids; see Birch et al. 2020).
[16] Schechter (2018: 231) mentions one case where the hemispheres seemed to wake and sleep separately; unfortunately, I could not find the reference.

twice as quickly if the search array is distributed across hemifields (Luck et al., 1994).[17] These findings suggest that each hemisphere has its own attentional focus or spotlight, which can be independently captured or used to scan its side of the visual field. Further supporting this idea, Mangun et al. (1994) found an attentional bias in the left hemisphere, which, regardless of task conditions, always benefits targets presented in the right visual field –as if the left hemisphere simply "attends" to its own field all the time. Contrastingly, the right hemisphere seems to selectively allocate or withdraw attention in response to task demands. Finally, it takes split-brain subjects twice as long to shift attention across the midline than within a single hemifield, even if the shift spans the same distance (Reuter-Lorenz and Fendrich, 1990; see Figure 7, right). This suggests that each side might rely on its own system for exogenous attentional capture; or, at the very least, that exogenous attention is more integrated within a hemisphere than across hemispheres (Schechter, 2018).

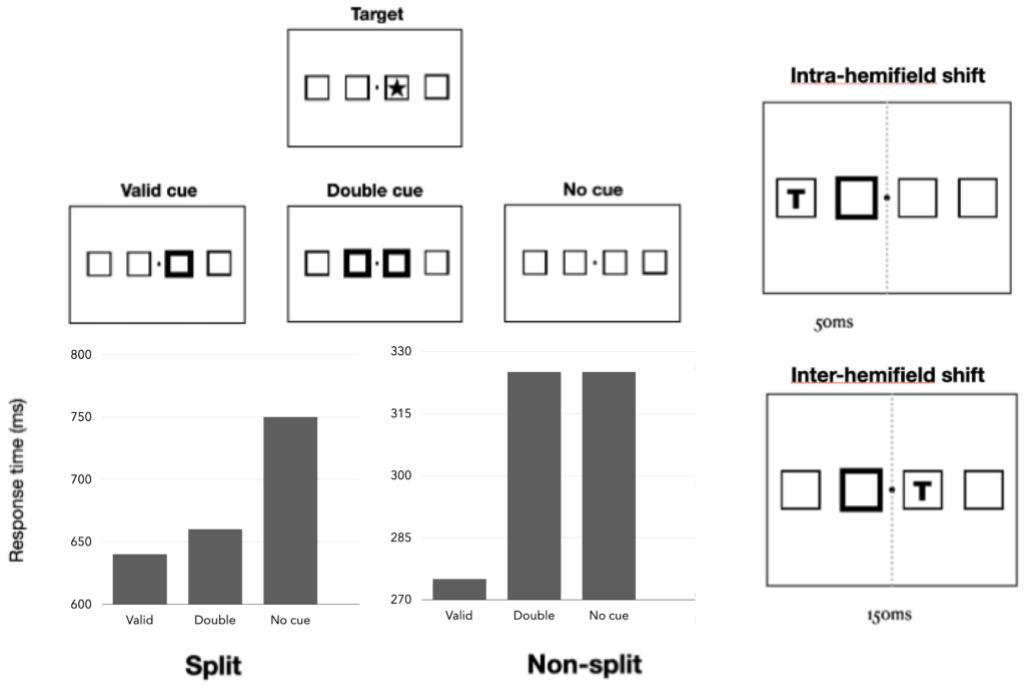

Figure 7. Breakdowns of exogenous attention.
Left: Bilateral cue advantage. Right: Inter-hemifield shifting cost.

In between the severe breakdown of exogenous reorienting and the preserved unity of alertness, moderate breakdowns are found in the top-down orienting and executive control functions. This means that these functions can continue working in a unified way, but only under certain conditions. Consider first top-down orienting, the voluntary and

[17] To be sure, non-split controls are *slightly* faster in bilateral searches, in accordance with the hemispheric division of labor in the non-split brain. However, the search rate was still similar to unilateral searches (with a difference of 5msec per item for non-split controls, and of 12msec per item for split-brain subjects). See Luck et al (1994: 85).

strategic direction of attention according to the organism's goals. Split-brain subjects can take advantage from two simultaneous endogenous cues, such as two arrows telling them where to direct attention (Arguin et al., 2000; see Figure 8). However, this benefit is only observed at very short cue-target intervals; when the interval is one second or longer, the effect disappears (Holtzman et al., 1984). This suggests that though the hemispheres may process endogenous cues independently at initial stages, they can still exchange some information for the control of visuo-spatial attention if allotted sufficient time (Arguin et al., 2000: 284). Thus, it is possible to speak of a moderate amount of remaining unity in the top-down orienting function. In this vein, Handy and Gazzaniga (2005, 361) say that though "each cerebral hemisphere can orient attention independently in response to bottom-up attentional cues, […] when attention is controlled by volitional decisions or top-down influences, the hemispheres appear to compete for control of a unitary focus."

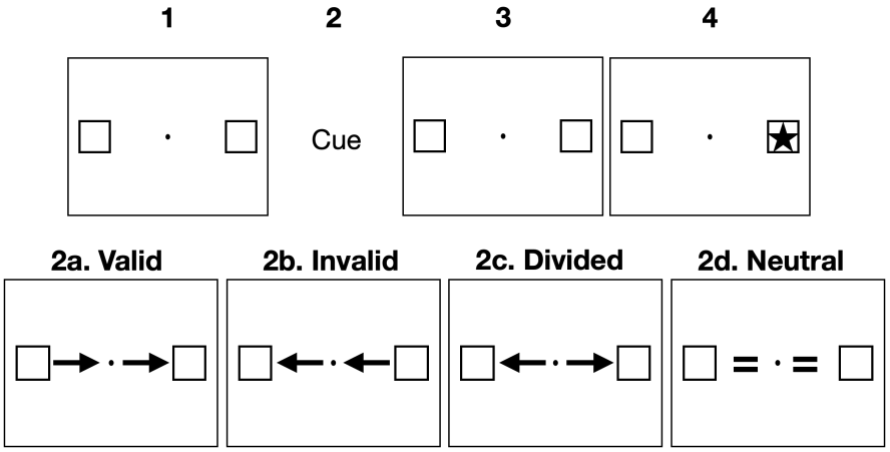

Figure 8. Bilateral endogenous cueing

Relatedly, executive control also retains a substantial amount of unity. This function concerns the ability to set and maintain the focus of attention on a specific task and is associated with the administration of the system's information processing resources. Evidence for the residual unity of this function is that when one hemisphere is given a difficult task, the other does worse in a simultaneous task (Holtzman and Gazzaniga, 1982). Relatedly, the attentional blink effect, which is linked to a limitation in processing resources, is comparable in split- and non-split subjects across visual hemifields (Ptito et al., 2009). These findings suggest that the hemispheres still compete for processing resources and control. However, other findings show that the competition is greater within a single hemisphere than between hemispheres, as more interference is observed between tasks relying on the same hemisphere than between tasks recruiting opposite hemispheres (Kreuter et al., 1972; Schechter, 2018). Moreover, split-brain subjects also exhibit great skill to perform different and even conflicting tasks with opposite hands during extended periods of time, such as sorting beads and nuts of different shapes in different ways

(Ellenberg and Sperry 1979, 1980). Thus, executive control can break down under certain conditions, while still working unitarily in others.

In these ways, attention in the split brain is neither totally unified nor totally disunified, as some attentional capacities break down or remain unified more than others. This gives us P2: Some attentional capacities are unified in the split brain. Then, by P1, we can conclude that phenomenal unity is neither totally preserved nor totally lost: Some amount of phenomenal unity remains in the split brain. This result aligns nicely with the claims of the layered unity model, especially the Conjoint Phenomenology Thesis.

As suggested above, the argument can be strengthened by highlighting the special relevance of the more unified attentional capacities (i.e., alertness, executive control and top-down orienting) for the unity-making relations of experienced centrality and attentional agency (as per Attention Based Phenomenal Unity; see Figure 9). The point is not just that some amount of attentional unity grants some phenomenal unity; rather, it is that unity in the right attentional capacities is sufficient for sustaining the unity-making relations.

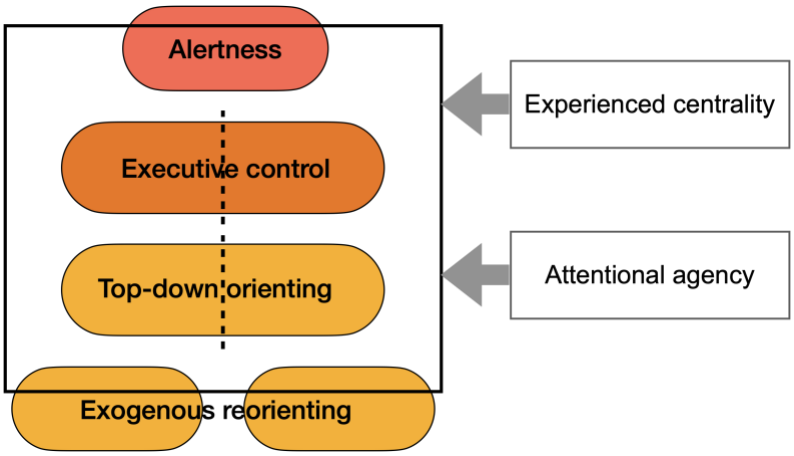

Figure 9. Attentional capacities and the unity-making relations

The links of attentional agency with top-down orienting and executive control are straightforward. Attentional agency requires subject control over what to attend to or how to distribute one's attention. Breakdowns in automatic attentional capture (i.e., exogenous reorienting) need not directly compromise attentional agency, even though they are the most severe. In this respect, the breakdowns in executive control and top-down orienting pose more of a threat for phenomenal unity, but as we have seen there is a substantial amount of preserved unity in these capacities.

For experienced centrality, exogenous attentional capture might have a more important role. If a salient item captures your attention (say, a sudden phone ring in a quiet library), your experience of this thing will suddenly feel more central than other concurrent experiences. Hence, when split-brain subjects have their attention simultaneously captured by two opposite-hemifield cues, it is tempting to ascribe them two different centrality systems. Suppose RE and LE occupy the right and left foci of attention. RE and LE are thus more central than other right and left experiential parts. But is either of RE and LE more central *than the other*, and *with respect to a common system* of centrality relations? Compare: You and I are drinking coffee while hearing bird chirping. I am focusing my attention on the chirping, while you focus yours on the coffee. My chirping experience is more central to me than your chirping experience is to you. It might also be more central to me than your coffee experience is to you. Still, there is no single centrality system comprising your experiences and mine. RE and LE could be like this. Watzl himself thinks that right and left experiential contents of split-brain subjects belong to different centrality systems. He proposes that full centrality structures shift from side to side, in the spirit of Bayne's switch model:

> When the patient attends left there is a centrality structure "on the left", while when she attends right there is a centrality structure "on the right". At no time is there a centrality structure with centrality relations holding *between* left and right. (Watzl, 2017: 284).

Still, one reason to resist the two centrality systems view, if based only on breakdowns of exogenous reorienting, is that automatic attentional capture can occur unconsciously.[18] But even granting that exogenous cues are consciously experienced, there is good reason for thinking that top-down orienting and executive control have at least as much weight, if not more, in determining relative centrality.[19] Even if a very salient object feels very central at the moment it captures attention, what is more important for centrality relations is what is more central *for the subject*, and thus top-down preferences, goals and intentions can triumph bottom-up salience. A baby crying loudly in an airplane is very salient, yet it might feel peripheral with respect to your inner ruminating.

In this respect, breakdowns in top-down orienting and executive control are more worrisome here, too. Indeed, Watzl notes that if the hemispheres were *structured around* processing different information, e.g., one is solving a mathematical problem while the other is attentively listening to a saxophone, that would be crucial evidence for *disunified streams* (Watzl, 2017: 284). Though such radical disunification does not seem to occur,

[18] I would say that split exogenous reorienting more likely generates two *priority* systems, but not necessarily two *centrality* systems. In Watzl's overarching view, centrality systems are the phenomenal reflection of systems of relative priorities, but "phenomenal holes" are admitted: Not all psychological parts are phenomenally reflected.

[19] Perhaps more, because of how Watzl conceives of attention and centrality relations as *subject-level activities* (Watzl, 2017: 33).

we have seen that the hemispheres can sometimes govern different tasks, each of which requires an amount of executive control (Ellenberg and Sperry, 1979, 1980).

To be sure, one could still argue that such tasks involve some level of automatization, and since automatized tasks arguably do not require consciousness, these performance patterns need not evince two separate phenomenal centres or centrality systems. Furthermore, one can also argue that if the hemispheres do in fact house separate experiential centres, these might be embedded into a single overarching centrality system, supported by the remaining unity in top-down orienting and executive control. Layers of experience could come in handy here: The overarching centrality system connects experiential parts in one layer, whereas the embedded right and left systems relate experiential parts in a different layer.

A single, overarching centrality system can also be supported by the unity of alertness. Experienced centrality likely depends on the amount of processing resources allocated to an experiential component. That is, experiencing E1 as more central than E2 plausibly requires allocating more processing resources to E1 and less to E2 (though see Velasquez et al., 2021). On the other hand, available processing resources seem to go together with levels of arousal and/or vigilance (Kim et al., 2017; see also Ásgeirsson and Nieuwenhuis, 2019). Then, to the extent that the hemispheres still draw on the same resource pool, it is plausible that how central an experience feels affects how central other experiences feel, regardless of side. If so, then right and left experiences, or some aspects thereof, plausibly belong to a single centrality system.

I have argued that the unity-making relations of attentional agency and experienced centrality are more supported by alertness, top-down orienting and executive control functions than on exogenous reorienting. However, I have not argued that alertness, top-down orienting and executive control are directly responsible for global unity, or that local unity breaks down because of exogenous reorienting breakdowns. Though some such connections appear plausible (for instance, between the alertness system and the global aspects of conscious experience[20]), I do not think there is a neat one-to-one mapping from attentional capacities to layers of experience. I find it more plausible that each attentional capacity could be involved in more than one layer of experience in different ways, along with other, non-attentional processes. For example, exogenous reorienting could be involved in the global layer by providing information about stimulus locations, while also being involved in the local layer by providing information about objects to be further categorised. I think these lines of thought allow for plausible elaborations, but for reasons of space I shall here leave them at this initial, speculative level.

[20] I am inclined to draw the connection between alertness and the global layer of experience via diffuse attention, a kind of attention dedicated to processing global properties just like those listed in the main text (Prettyman 2023).

5 Implications

Problematic cases like cross-matching inability suggest that phenomenal unity breaks downs in split-brain subjects, so that they lack conjoint conscious experiences of right- and left-side stimuli. I mentioned at the outset that such breakdown would suggest that phenomenal unity is not an essential property of subjective conscious experience. I also mentioned (echoing Pinto, Neville et al., 2017) that if phenomenal unity breaks down in split-brain subjects, this would be evidence that the mechanisms of *phenomenal* consciousness must involve large-scale informational integration in the cerebral cortex.

I have offered the layered unity model as a plausible way how right- and left-side experiences could be phenomenally unified even in the problem cases, via unity in the global aspects of experience (what I call "the global layer"). However, the model still admits phenomenal unity breakdowns in the local aspects ("the local layer"). What does this mean for our concept and theories of phenomenal consciousness?

If the layered unity model is an accurate description of split-brain *phenomenal* consciousness, three important things follow:

I$_1$. It is not *essential* to phenomenal consciousness to be *fully* unified.
I$_2$. Phenomenal unity is not an all-or-nothing property.
I$_3$. Phenomenal unity does not *completely* depend on cortical integrity or large-scale cortical communication.

Implications 1 and 2 primarily concern our concepts of phenomenal consciousness and phenomenal unity. Important questions called for by these claims are: How much disunity can be tolerated before we say that phenomenal unity has broken down? How much unity is necessary for phenomenal unity to be in place? Implication 3, in turn, is an empirical claim. If it holds, then the mechanisms of phenomenal unity are likely subcortical, or at least more localised within the cortex.

Notably, implications 1 and 3 are in tension with the tenets and predictions of one prominent theory in current consciousness science, the Integrated Information Theory (IIT). According to IIT's Axiom of Integration, phenomenal unity is an essential property of subjective experience (Albantakis et al., 2023; Hendren et al., 2024). This entails that no conscious experience of a subject at a time can fail to be unified. To be sure, if the layered unity model does afford phenomenal unity (as I claim it does –via unity in global experiential layers), then split-brain consciousness poses no counterexample to this axiom. But if the countenanced kind of unity requires unity in all aspects of experience, then my recommended layered unity does run counter to IIT's axiom. Nonetheless, the way phenomenal unity is conceived of within IIT need not entail so-called *full unity*. For IIT, unity is chiefly a matter of the irreducibility of an experience to its parts:

> I experience a whole scene, which cannot be reduced to seeing the left side of space separately from seeing the right side of space […] The experience of space cannot be subdivided into separate parts, such that, say, the left side of space existed without the right side, or the other way around.[21]

Prima facie, such irreducibility is compatible with breakdowns in local experiential layers. Consider again the offered picture:

(1) S experiences <right> at t
(2) S experiences <left> at t
(3a) S does not experience <right-&-left>$_{\text{LOCAL}}$ at t
(3b) S experiences <right-&-left>$_{\text{GLOBAL}}$ at t

Nothing in this picture says that S's experience at t reduces to the sum of:

- <right>$_{\text{LOCAL}}$
- <right>$_{\text{GLOBAL}}$
- <left>$_{\text{LOCAL}}$
- <left>$_{\text{GLOBAL}}$
- <right-&-left>$_{\text{GLOBAL}}$

IIT also predicts that when the two cerebral hemispheres are disconnected, conscious experience should split into two separate streams. This prediction is in line with the recent commitments of IIT to the sensory cortices as candidate neural bases of consciousness (Melloni et al., 2023). If the layered unity model is accurate, then this prediction of IIT is falsified. Or, at least, partly falsified: While, strictly speaking, split-brain surgery does not generate two separate streams of conscious experience, it does split one experiential *layer*. I take this to be a splitting *of consciousness* (rather than of *contents* of consciousness, as countenanced by Bayne, 2008). This means that IIT still tells a plausible story about *some* aspects of consciousness. One potential reason why it does not have the whole story is that this theory conceives of conscious experience as largely independent from the other cognitive capacities of conscious organisms, including attention. But if attention indeed plays a key role in generating phenomenal unity (as proposed by Watzl and Wiese), and perhaps even in generating phenomenal consciousness itself, then bringing attention into the picture is a needed step for IIT as well as for other theories of consciousness and conscious unity.

[21] This is an excerpt from Tononi's forthcoming book, *On Being*, Chapter 2: "The axioms of phenomenal existence", as cited in Hendren et al. (2024) (https://www.iit.wiki/axioms-and-postulates/integration#h.mel6wfyunh0i)

References

Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A. M., Marshall, W., Mayner, W. G. P., Zaeemzadeh, A., Boly, M., Juel, B. E., Sasai, S., Fujii, K., David, I., Hendren, J., Lang, J. P., & Tononi, G. (2023). Integrated information theory (IIT) 4.0: Formulating the properties of phenomenal existence in physical terms. *PLoS computational biology*, *19*(10), e1011465. https://doi.org/10.1371/journal.pcbi.1011465

Alvarez, George A., and Patrick Cavanagh. 2005. "Independent Resources for Attentional Tracking in the Left and Right Visual Hemifields." *Psychological Science* 16 (8): 637–643. 10.1111/j.1467-9280.2005.01587.x

Arguin, Michel, Maryse Lassonde, Antonio Quattrini, Marco Del Pesce, Nicola Foschi, and Isabelle Papo. 2000. "Divided Visuo-Spatial Attention Systems with Total and Anterior Callosotomy." *Neuropsychologia* 38 (3): 283–291. 10.1016/s0028-3932(99)00077-9

Ásgeirsson, Árni G., and Sander Nieuwenhuis. 2019. "Effects of Arousal on Biased Competition in Attention and Short-Term Memory. " *Attention, Perception & Psychophysics* **81**, 1901–1912. https://doi.org/10.3758/s13414-019-01756-x

Avvenuti, Giulia, Giovanni Handjaras, Matteo Betta, et al. 2020. "Integrity of Corpus Callosum Is Essential for the Cross-Hemispheric Propagation of Sleep Slow Waves: A High-Density EEG Study in Split-Brain Patients." *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience* 40 (29): 5589–5603. https://doi.org/10.1523/JNEUROSCI.2571-19.2020.

Bayne, Timothy J. 2008. "The Unity of Consciousness and the Split-Brain Syndrome." *Journal of Philosophy* 105 (6): 277-300. 10.5840/jphil2008105638

Bayne, Timothy J. 2010. *The Unity of Consciousness*. Oxford, GB: Oxford University Press UK.

Baynes, Kathleen, C. Mark Wessinger, Robert Fendrich, and Michael S. Gazzaniga. 1995. "The Emergence of the Capacity to Name Left Visual Field Stimuli in a Callosotomy Patient: Implications for Functional Plasticity." *Neuropsychologia*, *33*(10), 1225–1242. https://doi.org/10.1016/0028-3932(95)00039-6

Birch, Jonathan, Alexandra K. Schnell, and Nicola S. Clayton. 2020. " Dimensions of Animal Consciousness." *Trends in Cognitive Sciences* 24 (10): 789–801. https://doi.org/10.1016/j.tics.2020.07.007

Corballis. Michael C. 1994. "Perceptual Integration following Commissurotomy: A Reappraisal." In *New Horizons in Neuropsychology*, edited by M. Sugishita, 139-158. Elsevier Science, Amsterdam, 1994.

Corballis, Michael C. 1995. "Visual Integration in the Split Brain." *Neuropsychologia* 33, 937–959. https://doi.org/10.1016/0028-3932(95)00032-X

Corballis, Michael C. and Catherine I. Trudel. 1993. "The Role of the Forebrain Commissures in Interhemispheric Integration." *Neuropsychology* 7, 1-19, 1993.

Corballis, Michael C., Kyle J. Barnett, Mara Fabri, Aldo Paggi, and Paul M. Corballis, 2004. "Hemispheric Integration and Differences in Perception of a Line-Motion Illusion in the Divided Brain. " *Neuropsychologia*, *42*(13),1852–1857. https://doi.org/10.1016/j.neuropsychologia.2004.04.014

Corballis, Michael C., Peter M. Corballis, Giovanni Berlucchi, and Carlo A. Marzi. 2018. "Perceptual Unity in the Split Brain: The Role of Subcortical Connections," *Brain: A Journal of Neurology* 141, no. 6: e46, https://doi.org/10.1093/brain/awy085.

Corbetta, Maurizio, and Gordon L. Shulman. 2002. "Control of Goal-Directed and Stimulus-Driven Attention in the Brain." *Nature Reviews Neuroscience* 3 (2002): 201–215. PubMed: 11994752.

de Haan, Edward H. F., Paul M. Corballis, Steven A. Hillyard, et al. 2020. "Split-Brain: What We Know Now and Why This is Important for Understanding Consciousness." *Neuropsychology Review* 30, no. 2, 224–233. https://pubmed.ncbi.nlm.nih.gov/32399946/.

de Haan, Edward H. F., Mara Fabri, H. Chris Dijkerman, Nicoletta Foschi, Simona Lattanzi, and Yair Pinto. 2020. "Unified Tactile Detection and Localisation in Split-Brain Patients." *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior* 124, 217–223. https://doi.org/10.1016/j.cortex.2019.11.010.

Dell'Acqua, Roberto, Pierre Jolicoeur, Maryse Lassonde, Alessandro Angrilli, Pierluigi De Bastiani, and Angelo Pascali. 2005. "Unitary Attention in Callosal Agenesis." *Cognitive Neuropsychology* 22, no. 8, 1035–1053. https://pubmed.ncbi.nlm.nih.gov/21038288/.

Dehaene, Stanislas. 2014. *Consciousness and the Brain: Deciphering How the Brain Codes Our Thoughts.* Viking.

Dimond, Stuart J. 1979. "Performance by Split-Brain Humans on Lateralized Vigilance Tasks." *Cortex; A Journal Devoted to the Study of the Nervous System and Behavior*, *15*(1), 43–50. https://doi.org/10.1016/s0010-9452(79)80005-2

Downey, Adrian. 2018. "Split-brain Syndrome and Extended Perceptual Consciousness." *Phenomenology and the Cognitive Sciences* 17 (4):787-811.

Ellenberg, Leah, and Sperry, Roger W. 1979. "Capacity for Holding Sustained Attention Following Commissurotomy." *Cortex; A Journal Devoted to the Study of the Nervous System and Behavior*, 15(3), 421–438. https://doi.org/10.1016/s0010-9452(79)80068-4

Ellenberg, Leah, and Roger W. Sperry. 1980. "Lateralized Division of Attention in the Commissurotomized and Intact brain." *Neuropsychologia*, *18*(4-5), 411–418. https://doi.org/10.1016/0028-3932(80)90144-x

Fendrich, Robert, and Michael S. Gazzaniga. 1989. "Evidence of Foveal Splitting in a Commissurotomy Patient." *Neuropsychologia* 27, 273-281.

Forster, Bettina, and Michael C. Corballis. 2000. "Interhemispheric Transfer of Color and Shape Information in the Presence and Absence of the Corpus Callosum." *Neuropsychologia*, *38*(1), 32–45. https://doi.org/10.1016/s0028-3932(99)00050-0

Gazzaniga, Michael S. 1987. "Perceptual and Attentional Processes Following Callosal Section in Humans." *Neuropsychologia* 25: 119–33.

Gazzaniga, Michael. S., Joseph E. Bogen, and Roger W. Sperry. 1965. "Observations on Visual Perception After Disconnexion of the Cerebral Hemispheres in Man." *Brain: A Journal of Neurology*, *88*(2), 221–236. https://doi.org/10.1093/brain/88.2.221

Handy, Todd C., and Gazzaniga, Michael S. 2005. "Attention in Split-Brain Patients." In *Neurobiology of Attention*, edited by Laurent Itti, Geraint Rees and John K. Tsotsos, Academic Press.

Hines, Robert J., Lynn K. Paul, and Warren S. Brown. 2002. "Spatial Attention in Agenesis of the Corpus Callosum: Shifting Attention Between Visual Fields." *Neuropsychologia*, *40*(11), 1804–1814. https://doi.org/10.1016/s0028-3932(02)00032-5

Hendren, Jeremiah, Matteo Grasso, Bjørn Erik Juel, and Giulio Tononi. "Axioms & Postulates: From Phenomenology to Physics." *IIT Wiki*. Center for Sleep and Consciousness UW–Madison. Updated June 30, 2024. http://www.iit.wiki/axioms-and-postulates.

Holtzman, Jeffrey D. 1984. "Interactions between Cortical and Subcortical Visual Areas: Evidence from Human Commissurotomy Patients." *Vision Research*. 24(8):801-13. https://doi:10.1016/0042-6989(84)90151-2

Holtzman, Jeffrey D., and Michael S. Gazzaniga. 1982. "Dual Task Interactions Due Exclusively to Limits in Processing Resources." *Science* 218, 1325–1327.

Holtzman, Jeffrey D., Bruce T. Volpe and Michael S. Gazzaniga. 1984. "Spatial Orientation Following Commissural Section." In *Varieties of Attention*, edited by R. Parasuraman and D. R. Davies, 375-94, Montreal: Academic Press.

Kim, Dongho, Savannah Lokey, and Sam Ling. 2017. "Elevated Arousal Levels Enhance Contrast Perception." *Journal of Vision* 17(2):14. https://doi.org/10.1167/17.2.14.

Kreuter, Charles, Marcel Kinsbourne, and Colwyn Trevarthen. 1972. "Are Deconnected Cerebral Hemispheres Independent Channels? A Preliminary Study of the Effect of Unilateral Loading on Bilateral Finger Tapping." *Neuropsychologia*, *10*(4), 453–461. https://doi.org/10.1016/0028-3932(72)90008-5

Johnson, Larry E. 1984. "Bilateral Visual Cross-Integration by Human Forebrain Commissurotomy Subjects. " *Neuropsychologia*, *22*(2), 167–175. https://doi.org/10.1016/0028-3932(84)90059-9

Làdavas, Elisabetta, Maria Del Pesce, George R. Mangun and Michael S. Gazzaniga. 1994. "Variations in Attentional Bias of the Disconnected Cerebral Hemispheres." *Cognitive Neuropsychology*, *11*(1), 57–74. https://doi.org/10.1080/02643299408251966

Lamme V. A. (2006). Towards a true neural stance on consciousness. *Trends in cognitive sciences*, *10*(11), 494–501. https://doi.org/10.1016/j.tics.2006.09.001

Levy, Jerre, Colwyn Trevarthen and Roger W. Sperry. 1972. "Perception of Bilateral Chimeric Figures Following Hemispheric Deconnexion. " *Brain: A Journal of Neurology*, *95*(1), 61–78. https://doi.org/10.1093/brain/95.1.61

Levy, Jerre, and Colwyn Trevarthen. 1981. "Color-Matching, Color-Naming and Color-Memory in Split-Brain Patients." *Neuropsychologia*, *19*(4), 523–541. https://doi.org/10.1016/0028-3932(81)90019-1

Luck, Steven J., Steven A. Hillyard, George R. Mangun, and Michael S. Gazzaniga. 1994. "Independent Attentional Scanning in the Separated Hemispheres of Split-Brain Patients." *Journal of Cognitive Neuroscience.* 6(1):84–91

Mangun, George R., Steven J. Luck, R. Plager, W. Loftus, Steven A. Hillyard, Todd Handy, V. P. Clark, and Michael S. Gazzaniga. 1994. "Monitoring the Visual World: Hemispheric Asymmetries and Subcortical Processes in Attention." *Journal of Cognitive Neuroscience*, 6(3), 267–275. https://doi.org/10.1162/jocn.1994.6.3.267

Mascetti, Gian G. 2016. "Unihemispheric Sleep and Asymmetrical sleep: Behavioral, Neurophysiological, and Functional Perspectives." *Nature and Science of Sleep*, 8, 221–238. https://doi.org/10.2147/NSS.S71970

Melloni, L., Mudrik, L., Pitts, M., Bendtz, K., Ferrante, O., Gorska, U., Hirschhorn, R., Khalaf, A., Kozma, C., Lepauvre, A., Liu, L., Mazumder, D., Richter, D., Zhou, H., Blumenfeld, H., Boly, M., Chalmers, D. J., Devore, S., Fallon, F., de Lange, F. P., … Tononi, G. (2023). An adversarial collaboration protocol for testing contrasting predictions of global neuronal workspace and integrated information theory. *PloS one*, *18*(2), e0268577. https://doi.org/10.1371/journal.pone.0268577

Milner, A. David, Monika Harvey, Richard C. Roberts, and S.V. Forster. 1993. "Line Bisection Errors in Visual Neglect: Misguided Action or Size Distortion?" *Neuropsychologia* 31(1):39-49. doi: 10.1016/0028-3932(93)90079-f. PMID: 8437681.

Naikar, Neelam. 1996. "Perception of Apparent Motion of Colored Stimuli After Commissurotomy." *Neuropsychologia* 34: 1041–9.

Naikar, Neelam, and Michael C. Corballis. 1996. "Perception of Apparent Motion Across the Retinal Midline After Commissurotomy." *Neuropsychologia* 35: 297–309.

Newen, Albert, and Carlos Montemayor. 2023. "The ALARM Theory of Consciousness: A Two-Level Theory of Phenomenal Consciousness." *Journal of Consciousness Studies* 30 (3):84-105.

Pashler, Harold, Steven J. Luck, Steven A. Hillyard, George R. Mangun, Shannon O'Brien and Michael S. Gazzaniga. 1994. "Sequential Operation of Disconnected Cerebral Hemispheres in Split-Brain Patients." *Neuroreport*, *5*(17), 2381–2384. https://doi.org/10.1097/00001756-199411000-00042

Petersen, Steven E., and Michael I. Posner. 2012. "The Attention System of the Human Brain: 20 Years After." *Annual Review of Neuroscience*, *35*, 73–89. https://doi.org/10.1146/annurev-neuro-062111-150525

Pinto, Yair, David A. Neville, Marte Otten, Paul M. Corballis, Victor A. F. Lamme, Edward H. F. de Haan, Nicoletta Foschi, and Mara Fabri. 2017. "Split Brain: Divided Perception but Undivided Consciousness." *Brain*. May 1;140(5):1231-1237.

Pinto, Yair, Edward H. F. de Haan, and Victor A. F. Lamme. 2017. "The Split-Brain Phenomenon Revisited: A Single Conscious Agent with Split Perception." *Trends in Cognitive Sciences*, *21*(11), 835–851. https://doi.org/10.1016/j.tics.2017.09.003

Pitts, Michael A., Lyuda A. Lutsyshyna, and Steven A. Hillyard. 2018. "The Relationship between Attention and Consciousness: An Expanded Taxonomy and Implications for 'No-report' Paradigms." *Philosophical Transactions of the Royal Society B* 373 (1755): 20170348. https://doi.org/10.1098/rstb.2017.0348.

Prettyman, Adrienne. 2023. "What Is Diffuse Attention? " *Mind & Language*, 38(2), 374–393. https://doi.org/10.1111/mila.12365

Ptito, Alexia, Benoit Brisson, Roberto Dell'Acqua, Maryse Lassonde and Pierre Jolicoeur. 2009. "The Attentional Blink Within and Across the Hemispheres: Evidence from a Patient with a Complete Section of the Corpus Callosum." *Biological Psychology*, *82*(1), 64–69. https://doi.org/10.1016/j.biopsycho.2009.06.001
Ramachandran, Vilayanur S., Alice Cronin-Golomb, and Jay J. Myers. 1986. "Perception of Apparent Motion by Commissurotomy Patients." *Nature* 320, 358–359.
Reuter-Lorenz, Patricia A., and Robert Fendrich. 1990. "Orienting Attention across the Vertical Meridian: Evidence from Callosotomy Patients." *Journal of Cognitive Neuroscience*, *2*(3), 232–238. https://doi.org/10.1162/jocn.1990.2.3.232

Savazzi, Silvia, Mara Fabri, Guido Rubboli, Aldo Paggi, Carlo A. Tassinari, and Carlo A. Marzi. 2007. "Interhemispheric Transfer Following Callosotomy in Humans: Role of the Superior Colliculus." *Neuropsychologia*, *45*(11), 2417–2427. https://doi.org/10.1016/j.neuropsychologia.2007.04.002

Schechter, Elizabeth. 2018. *Self-Consciousness and Split Brains: The Minds' I*. Oxford, UK: Oxford University Press.

Schechter, Elizabeth. 2014. "Partial Unity of Consciousness: Evidence and Implications." In *The Unity of Consciousness and Sensory Integration*, edited by David J. Benett and Christopher Hill, 347–73, MIT Press.

Schechter, Elizabeth, and Timothy J. Bayne. 2021. "Consciousness After Split-Brain Surgery: The Recent Challenge to the Classical Picture." *Neuropsychologia*, *160*, 107987. https://doi.org/10.1016/j.neuropsychologia.2021.107987.

Sergent, Justine. 1986. "Subcortical Coordination of Hemisphere Activity in Commissurotomized Patients." *Brain: A journal of Neurology*, 109 (Pt 2), 357–369. https://doi.org/10.1093/brain/109.2.357

Sergent, Justine. 1987. "A New Look at the Human Split Brain." *Brain* 110, 1375-1392.

Sperry, Roger W. 1968. "Hemisphere Deconnection and Unity in Conscious Awareness." *The American Psychologist*, 23(10), 723–733. https://doi.org/10.1037/h0026839

Sperry, Roger W. 1982. "Some Effects of Disconnecting the Cerebral Hemispheres." *Science* 217(4566), 1223–1226. https://doi.org/10.1126/science.7112125.

Teng, Evelyn L., and Roger W. Sperry. 1973. "Interhemispheric Interaction During Simultaneous Bilateral Presentation of Letters or Digits in Commissurotomized Patients." *Neuropsychologia*, *11*(2), 131–140. https://doi.org/10.1016/0028-3932(73)90001-8

Teng, Evelyn L., and Roger W. Sperry. 1974. "Interhemispheric Rivalry During Simultaneous Bilateral Task Presentation in Commissurotomized Patients." *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*, *10*(2), 111–120. https://doi.org/10.1016/S0010-9452(74)80002-X

Tononi, G., & Koch, C. (2015). Consciousness: here, there and everywhere? *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *370*(1668), 20140167. https://doi.org/10.1098/rstb.2014.0167

Tramo, Mark, Kathleen Baynes, Robert Fendrich, George R. Mangun, Elizabeth A. Phelps, Patricia A. Reuter-Lorenz, and Michael S. Gazzaniga. 1995. "Hemispheric

Specialization and Interhemispheric Integration: Insights from Experiments with Commissurotomy Patients." In *Epilepsy and the corpus callosum* (vol. 2), edited by A. Reeves and D. Roberts, 263–95. Plenum Press

Velasquez, Anthony G., Adam Gazzaley, Heishiro Toyoda, David A. Ziegler, and Ezequiel Morsella. 2021. "The Generation of Involuntary Mental Imagery in an Ecologically-Valid Task." *Frontiers in Psychology*, 12, 759685. https://doi.org/10.3389/fpsyg.2021.759685

Volz, Lukas J., and Michael S. Gazzaniga. 2017. "Interaction in Isolation: 50 Years of Insights from Split-Brain Research." *Brain*, 140(7), 2051-2060.

Watzl, Sebastian. 2014. "Attentional Organization and the Unity of Consciousness." *Journal of Consciousness Studies* 21 (7–8): 56–87. http://www.ingentaconnect.com/content/imp/jcs/2014/00000021/F0020007/art00004.

Watzl, Sebastian. 2017. *Structuring Mind*. Oxford: OUP.

Wiese, Wanja. 2022. "Attentional Structure and Phenomenal Unity." *Open Philosophy* 5 (1): 254–264. https://doi.org/10.1515/opphil-2022-0197