the british psychological society
promoting excellence in psychology

Journal of Neuropsychology (2021), 15, 1–19

www.wileyonlinelibrary.com

Theoretical or Review Article

Singularity and consciousness: A neuropsychological contribution

Edward H. F. de Haan*[1,2], Huibert Steven Scholte[1,2], Yair Pinto[1,2], Nicoletta Foschi[3], Gabriele Polonara[4] and Mara Fabri[5]

[1]Department of Psychology, University of Amsterdam, the Netherlands
[2]Amsterdam Brain & Cognition (ABC) Center, University of Amsterdam, the Netherlands
[3]Epilepsy Center-Neurological Clinic, Azienda "Ospedali Riuniti", Ancona, Italy
[4]Department of Odontostomatologic and Specialized Clinical Sciences, Marche Polytechnic University, Ancona, Italy
[5]Department of Experimental and Clinical Medicine, Marche Polytechnic University, Ancona, Italy

In common sense experience based on introspection, consciousness is singular. There is only one 'me' and that is the one that is conscious. This means that 'singularity' is a defining aspect of 'consciousness'. However, the three main theories of consciousness, Integrated Information, Global Workspace and Recurrent Processing theory, are generally not very clear on this issue. These theories have traditionally relied heavily on neuropsychological observations and have interpreted various disorders, such as anosognosia, neglect and split-brain as impairments in conscious awareness without any reference to 'the singularity'. In this review, we will re-examine the theoretical implications of these impairments in conscious awareness and propose a new way how to conceptualize consciousness of singularity. We will argue that the subjective feeling of singularity can coexist with several disunified conscious experiences. Singularity awareness may only come into existence due to environmental *response* constraints. That is, perceptual, language, memory, attentional and motor processes may largely proceed unintegrated in parallel, whereas a sense of unity only arises when organisms need to respond coherently constrained by the affordances of the environment. Next, we examine from this perspective psychiatric disorders and psycho-active drugs. Finally, we present a first attempt to test this hypothesis with a resting state imaging experiment in a split-brain patient. The results suggest that there is substantial coherence of activation across the two hemispheres. These data show that a complete lesioning of the corpus callosum does not, in general, alter the resting state networks of the brain. Thus, we propose that we have separate systems in the brain that generate distributed conscious. The sense of singularity, the experience of a 'Me-ness', emerges in the interaction between the world

**Correspondence should be addressed to Edward de Haan, Psychology Department, University of Amsterdam, Nieuwe Prinsengracht 129B, 1018WS Amsterdam, the Netherlands (email: e.h.f.dehaan@uva.nl).*

DOI:10.1111/jnp.12234

and response-planning systems, and this leads to coherent activation in the different functional networks across the cortex.

In most theories, and certainly in common sense experience based on introspection, consciousness is singular. There is only one 'me' and that is the one that is conscious. This means that 'singularity' is a defining aspect of 'consciousness'. Bayne (2008, 2010); Bayne and Chalmers (2003) distinguish different definitions of unified consciousness, and in one sense, singularity refers to 'subject unity'. Subject unity is present if all the experiences generated in a system belong to one subject. In other words, if a system contains a first-person perspective, then subject unity is preserved if that system only contains one such perspective, but subject unity is absent if the system contains multiple first-person perspectives. Another definition of unified consciousness refers to representational unity. This indicates whether the contents of an experience are integrated. For instance, when you are driving a car and listening to GPS instructions, your sight and sound are related to each other, whereas if you listen to the radio, the visual and auditory contents are not integrated (Sasai, Boly, Mensen, & Tononi, 2016). So, representational unity is preserved in the former, but not in the latter case. Thus, the existence of a singularity refers to subject unity: One subject undergoes all the experiences existing within a system. Representational unity is more closely related to the sense of singularity, or the 'feeling of oneness'. This distinction bears some resemblance to the 'subjective self' and the 'objective self'. The former refers to the sense of self, whereas the latter refers to the self as an experiencer.

The currently leading theories on consciousness in cognitive neuroscience are the Integrated Information theory (IIT, Tononi, 2004, 2005; Tononi & Koch, 2015), the Global Workspace theory (Baars, 1988, 2005; Dehaene & Naccache, 2001), and the Recurrent Processing theory (Block, 2007; Lamme, 2006; Lamme & Roelfsema, 2000). According to IIT, consciousness arises when a system has a rich representation repertoire and its subsystems are strongly interconnected. However, when the integration within a subsystem is larger than the connection between subsystems, consciousness will arise as a function of the subsystem rather than of the system as a whole (Tononi, 2004, 2005). Thus, this theory suggests that split-brain patients, in whom integrated information processing is mostly confined within the two hemispheres, are two conscious agents; one agent per hemisphere. Note that this seems to refer to subject unity, or the objective self. According to Global Workspace theory, the cerebral hemispheres house a 'global workspace'. This global workspace can be thought of as the 'headquarters' of the cortex, which receives information from and projects to many cortical modules. Only information processed by the global workspace reaches consciousness. Recurrent Processing theory asserts that consciousness can arise through local recurrent processing between cortical modules, even in the absence of global or integrative cortical processes. However, such local processing, by itself, only leads to phenomenal consciousness that is otherwise inaccessible, and unreportable. Thus, for unified *reportable* consciousness, strong integration between the hemispheres is needed. These models all share the idea that unified consciousness requires massive, coherent activation of neuronal tissue in the brain. Note that in these theories, no clear distinction is made between the sense of self and the existence of a self. For instance, IIT seems to claim that in a split-brain two first-person perspectives exist. That is, there really are two independent conscious agents in a split-brain, one per hemisphere. IIT is silent on how the sense of self is impacted. In theory, even if there are two agents, they could still (mistakenly) think of themselves as only one agent. In general, none of the leading theories of consciousness clearly

distinguishes between the objective and subjective self, and none clearly indicate which processes underlie either of these selves.

Here, we will address this lacuna. We will postulate a model that deals with the subjective self, that is, the sense of singularity. Our model is grounded on three main hypotheses. The first hypothesis states that conscious awareness is distributed (e.g., Weiskrantz, 1999). The conscious experience of perceptual, language, memory, attentional and even motor processes may largely proceed unintegrated in parallel. Thus, this addresses, in Bayne's terms, representational unity, not subject unity. That is, we claim that many conscious processes may contribute to experiences with parts that are not integrated with each other (comparable to movies in which sound and sight are out-of-sync) although they still all may be experienced by one subject.

The second hypothesis argues that the subjective feeling of singularity, that is, the subjective self, can coexist with several disunified conscious experiences. The sense of singularity, then, is an experience that may only come into existence when we need to move our (single) body in an environment characterized by *response* constraints. Thus, conscious awareness may largely proceed unintegrated in parallel, whereas the sense of unity only arises when organisms need to respond coherently and purposefully. The third hypothesis suggests that the sense of singularity is based on a separate neural system involving an extensive subcortical network (e.g., the thalamus and the striatum), prefrontal, and insular structures that is concerned with developing intentions and action plans.

Regarding the first hypothesis, note that many studies with healthy subjects on attention claim that 'the brain cannot process all incoming information, therefore we need selection by means of attention' – the so-called early selection idea of attention (Broadbent, 1958; Neisser & Becklen, 1975; Yantis & Johnston, 1990). However, this claim may be erroneous, since the brain can, and in fact does, process massive incoming information in parallel. As far as selection takes place, it is mainly outside the purview of top-down attention. This is also apparent from our visual experience. In contrast to the claims stating that 'change blindness' is driven by consciousness bottlenecks, it is evident that you experience a lot of visual information at the same time without needing attention. Parallel processing even occurs in attention as has been shown by 'multiple object tracking' studies (Alvarez & Cavanagh, 2005; Cavanagh & Alvarez, 2005; Drew, Mance, Horowitz, Wolfe, & Vogel, 2014) and 'functional split-brain' (Sasai et al., 2016) investigations. In all these perceptual examples, there is no place in the brain where all the visual information comes together. The notion of a single phrenological seat for consciousness seems like a highly improbable explanation of the sense of singularity. After all, even within a single cortical area, information is distributed, and it is impossible that eventually all information is projected onto a single neuron.

In contrast, we suggest that the sense of singularity does not arrive as a by-product from having one seat of consciousness but is the result of the interaction between intentions and the possibilities or affordances of our body, and the environment. This system is, typically, single because, although there are many different input channels signalling different aspects of the outside world and many response possibilities, there is, however, only one body in one environment. Motor control is effected at many levels, ranging from spinal reflexes to subcortical, cerebellar, and cortical systems. Therefore, we are able to execute complex and sometimes conflicting behaviours. However, at the highest level, we formulate intentions and develop action plans that concern a single body in an external world that allows to successfully satisfy some but no other intentions. The second hypothesis thus argues that our experience of a singular 'Me' finds its origin in this

intentional, action directed process. It is not the binding of different cognitive processes that causes this experience but the need to satisfy intentions using your body. We are, thus, hypothesizing a Gibsonian (e.g., Gibson, 1979) interpretation of the sense of singular agency. The third hypothesis is more speculative and suggests that this intentional singularity system has evolved in a phylogenetic fashion from a basic subcortical system for motor planning to a high-level cognitive system involving the prefrontal and insular regions. Our starting point here is similar to the 'Passive Frame Theory' proposed by Morsella, Godwin, Jantz, Krieger, and Gazzaley (2016), who proposed a framework from an action-based perspective. They suggest that the primary function of consciousness is serving the somatic nervous system: 'it constrains and directs skeletal muscle output, thereby yielding adaptive behavior. The mechanism by which consciousness achieves this is more counterintuitive, passive, and "low level" than the kinds of functions that theorists have previously attributed to consciousness'. They propose two separate types of consciousness: *paleoconsciousness* that originates in a phylogenetically old system like the olfactory system, and *neoconsciousness* that arising from thalamic and cortical processing. We agree that environmental and bodily affordances are important but we disagree with their focus on the olfactory system and the somatosensory system. More importantly, we do not concur with the suggestion that this system subserves consciousness as a whole but propose instead that such a system might explain the sense of singularity. Therefore, our suggestion is more in line with the commentary of de Vries and Ward (2016), who also start with claim that the environment affords many possible actions. They suggest that we have perceptual, cognitive and motor systems that afford such a huge number of possible actions that there is a need for constraints. They propose that the more elaborate *neoconsciousness* system based on a subcortical network evolved, along with neocortex, to extend the range of affordances, thereby providing a basis for very sophisticated behaviours involve moving the body and limbs in complicated ways. These action affordances develop in environment-specific settings, but experience enables us to extend these behaviours to novel projections in space and time. Subsequently, it allows for the planning of complex movement patterns well beyond the range of direct perception.

In addition, communication is also an interaction between a person and his or her environment. Speaking allows for endless different messages to be shared with the environment, but it is essentially singular: You simply cannot say two things at once. Then, it might follow that higher-order thinking (in the sense of verbal thought) is also experienced as singular. That is, it is also under the control of the singularity constraints. That means that you can consciously think of all kinds of different things at the same time (parallel, pre-verbal notions), but if you want to translate it into language (speaking or internal speech), it will become singular. If that makes sense, it means that the 'function' that monitors or imposes singularity is within the brain's functions that regulate our intentions in the environment. As a first approximation, it is likely to be based on a phylogenetically older subcortical network and cortically distributed over the frontal/parietal areas (but it does not have to be in one separate area). In addition, it is possible that the insula, as a higher-order emotional representation of the body, is also involved (e.g., Morsella et al., 2016).

Below, we will re-examine the theoretical implications of the neuropsychological impairments in conscious awareness against the backdrop of our new hypothesis. Subsequently, we present a first attempt to test this hypothesis with a resting state imaging experiment in a split-brain patient.

Impairments in conscious awareness

Theories of consciousness have traditionally relied heavily on neuropsychological observations. Clinical observations of disorders in neurological patients can often be interpreted as impairments in conscious awareness. Until recently, the consensus appeared to be that the main theories of consciousness were largely in agreement with these neuropsychological observations. However, on occasion these observations are open to alternative interpretations, and in some cases, the phenomenology has been reassessed as new evidence was collected. There are basically four groups of these neuropsychological phenomena: anosognosia or denial of illness, knowledge without awareness, neglect and split-brain. We will critically evaluate the conclusions that may be drawn from these observations with respect to consciousness in the light of our new approach.

Anosognosia or denial of illness

The classic observations of unawareness of impairment date back to Von Monakow (1885) and Anton (1899) whose patients denied their own blindness or deafness. Soon it became clear that it can occur in a wide range of physical and cognitive disorders, such as unawareness of hemiplegia (Babinski, 1914), hemianopia (Critchley, 1949; Warrington and Weiskrantz, 1968), aphasia (Lebrun, 1987; Wernicke, 1874), and of amnesia (Korsakoff, 1889; Talland, 1961, 1965). Anosognosia cannot be explained by the severity of impairment. For instance, on the basis of a review of the different causes of unawareness of memory impairments McGlynn and Schacter (1989) concluded that it is clearly not simply the case that people with poor memories forget the occasions when they failed to remember things and thus feel that their memories are unimpaired. In addition, McGlynn and Schacter (1989) also argued that the patients who show unawareness of impairment are not necessarily demented and do not necessarily experience a global change in consciousness. In contrast, patients who are disoriented and confused may nonetheless continue to achieve insight into their cognitive impairments (Parkin, Miller, & Vincent, 1987). Thus, there is convincing evidence for a 'double dissociation' between anosognosias and more general impairments of consciousness. Another important point is that patients with more than one deficit may be unaware of one impairment but perfectly well aware of others. Von Monakow (1885) had already observed that a patient with extensive bilateral brain lesions who denied being blind but complained heavily about other problems. This idea has been further expanded by Bisiach, Vallar, Perani, Papagno, and Berti (1986), who showed clear dissociations between anosognosia for hemiplegia and anosognosia for hemianopia. The fact that anosognosia may be very selective was demonstrated in a patient reported by Young, de Haan, and Newcombe (1990) who suffered from multiple cognitive deficits but only denied her face recognition impairment. Interestingly, Anton (1899) already suggested that 'unawareness of impairment of a particular function is caused by a disorder at the highest levels of organization of that function'. The deficits of insight have also been observed in dementias and psychiatric conditions, such as schizophrenia (e.g., David, Bedford, Wiffen, & Gilleen, 2012).

Thus, the clinical phenomenon of anosognosia actually suggests that local consciousness (of a deficit in a particular processing stream) may become selectively disrupted. The alternative proposal that anosognosia is caused by a disconnection between a specific cognitive module and a central 'awareness system' (e.g., Schacter, McAndrews, & Moscovitch, 1988; see also Schacter's (1989) 'DICE' [Dissociative Interactions in

Conscious Experience] model) assumes that we possess such a separate system where consciousness arises. There is little empirical evidence for such a system. It is, therefore, not such a strange suggestion to conclude that with respect to perception, body awareness, and memory, we have multiple unintegrated streams of consciousnesses and that these streams differ in terms of detail and vividness. We might be vaguely aware of the room temperature, somewhat aware of the phone in our pocket and very aware of a person in the room that we do not like. Damage to a network may cause – in certain circumstances – that insight about its dysfunctional state does not reach consciousness. Note that, as a rule, the experience of singularity is not reduced in these patients.

Knowledge without awareness

There is a group of clinical phenomena that can be construed as spared cognitive processing while the patient remains consciously oblivious of the fruits of this processing. We will discuss a number of the most prominent examples below.

The paradoxical term 'blindsight' refers to the ability of patients, who suffer from visual field defects due to damage to the primary visual cortex, to respond above chance to visual stimuli in the blind areas of their visual field. The first clinical report was published in 1973 by Pöppel et al. who demonstrated that hemianopic patients made accurate saccades to light flashes presented in their blind half-field. Weiskrantz (e.g., Sanders, Warrington, Marshall, & Weiskrantz, 1974; Weiskrantz, 2009; Weiskrantz, Warrington, Sanders, & Marshall, 1974) took this initial observation one step further and showed that the effects could also be demonstrated using manual pointing and verbal forced-choice responses. Apart from blindsight for location, it has since been argued that blindsight patients may respond to flicker, contrast sensitivity, motion, and wavelength (e.g., Stoerig & Cowey, 1992). In addition, above-change processing of higher-order properties has also been proposed (e.g., Tamietto & Morrone, 2016). For instance, Trevarthen et al. (2007) argued for preserved categorical perception, and Solca et al. (2015) for recognition of familiar faces presented in the blind field. Earlier criticism (e.g., Campion, Latto, & Smith, 1983) focused on alternative explanations such as scattered light and/or rudimentary ('peppered') vision. Subsequent research refuted most these criticisms in subsequent studies (see Cowey, 2010 for a review) but it also became clear that there are different types of blindsight phenomenon in different, individual patients. In response to differences in the phenomenal experience of patients, two forms of it have been proposed by Weiskrantz (1998). In type 1 blindsight, the patients experience no awareness of any kind, while patients with type 2 blindsight experience a non-visual experience that, and even where, something occurred. In addition, Danckert and Rossetti (2005) suggested three different types of blindsight. First, patients who are able to act upon stimuli in the blind field (e.g., by pointing or saccades) are classified as having 'action-blindsight'. Second, patients who respond on the basis of attentional processing of blind field stimuli are thought to have 'attention-blindsight', and third, patients who demonstrate above-chance perceptual judgements for different stimulus characteristics presented in the blind field are classified as having 'perceptual blindsight' (Smits et al., 2019).

Covert face recognition concerns the indirect observation of preserved face processing in prosopagnosic patients. The term 'prosopagnosia' (Bodamer, 1947) refers to an inability to recognize familiar people by the face as a result of bilateral occipitotemporal lesions. The perception of faces as such remains intact, and they can

describe a face and see the features such as the nose and the eyes clearly. In addition, the recognition of other objects is still intact (e.g., de Haan, 2017, 2019; De Renzi, 1986). The first demonstrations of covert recognition relied on autonomic and central physiological responses that are sensitive to familiarity or identity. Bauer (1984) showed a prosopagnosic patient a series of photographs of familiar faces each time with five spoken names. The patient was at chance in choosing the correct name but electrodermal responses differentiated between target names and foils. Rizzo, Hurtig, and Damasio (1987) showed that visual scan paths differed between familiar and unfamiliar faces and that this effect was also present in a prosopagnosic patient, while Renault, Signoret, DeBruille, Signoret, Debruille, Breton, and Bolgert (1989) observed significant differences in the P300 responses to familiar versus unfamiliar faces in a patient with prosopagnosia. Using behavioural tests employing paradigms such as interference and priming, de Haan et al. confirmed that in some patients the recognition ability was largely intact and it was only the absence of conscious access to this information that caused the prosopagnosia (de Haan et al., 1987; de Haan, Bauer, & Greve, 1992; Young, Hellawell, & De Haan, 1988; Young and Haan, 1988). For instance, a priming task was used in which the patient was asked to make speeded responses to familiar and unfamiliar names (he could still read). The amount of priming (i.e., RT reduction) was similar from name primes, which could recognize, and face primes, that he could not recognize overtly. Similar observations have also been reported in the realm of alexic, letter-by-letter reading patients (Coslett & Saffran, 1990; Shallice and Saffran, 1986).

Implicit processing has been extensively investigated in memory. From the early studies in the famous patient HM demonstrating spared motor learning on a mirror drawing task (Milner, 1962) and the observation of intact perceptual fluency in amnesic patients by Warrington and Weiskrantz (1968) to the large-scale research programmes by Schacter (Schacter, 2020) and Squire (2009). Implicit memory can be demonstrated with tasks such as the word-stem-completion where patients have complete word-stems with the first word that comes to mind instead of asking them to remember which word has been presented earlier (e.g., Schacter, Alpert, Savage, Rauch, & Albert, 1996) or similar priming paradigms for verbal and non-verbal material. Implicit access has also been demonstrated for semantic memory (Young, Newcombe, Hellawell, & de Haan, 1989), and Graf and Schacter (1985) showed that amnesic patients can even store new associations at an implicit level.

What has not been stressed, but now constitutes an important data point, is the observation that patients with comorbid deficits do not show knowledge without awareness across the board. Thus, a patient with prosopagnosia and amnesia may show covert face recognition but does not – as rule – show any evidence for implicit memory, and vice versa. Thus, the clinical condition dampening consciousness below the level at which it can still be experienced is a local phenomenon. It only affects a particular function, and the remaining functions appear to provoke consciousness in a normal fashion. The experience of singularity is not normally affected in these patients.

Neglect

This concerns a group of related disorders that entail a failure to report, react or orient to stimuli that are presented to the patient's contralesional side (e.g., Heilman, Watson, and Valenstein, 1985). The responsible lesions are in the right superior longitudinal fasciculus and its cortical end-points in the parietal and frontal lobes (Lunven et al., 2015). It is not

caused by a basic sensorimotor deficit or general confusion or intellectual deterioration. Different subtypes of neglect are distinguished. Neglect at the input-level concerns impairments in the perception of, or the attention to, the hemifield contralateral to the damaged hemisphere, while problems at the output or intentional stage are concerned with motor (akinesithetic) deficits in or towards the contralesional side. Moreover, the characteristics of the deficit (Heilman et al., 1985; Halligan, Marshall, & Wade, 1989; Heilman, Valenstein, & Watson, 2000) are further determined by the spatial frame-of-reference (personal, spatial, and representational) and the responding hand (unimanually left or right or bimanual). Central for the current discussion is that neglect is in essence a form of selective unawareness. The complete outside world is registered, and there is good evidence that the information is processed at an implicit level (e.g., Berti & Rizzolatti, 1992). Thus, neglect is an example of knowledge without awareness *and* anosognosia in the same patient (see also Young et al., 1990). Explaining their failure to the patient has little effect; it is as if he or she has also forgotten what it was like to attend to the left side. Thus, apart from an impairment in the conscious perception or explicit memory, brain damage can also result in an inability to consciously explore or attend to part of the external world. In short, in all its different forms, neglect constitutes an intriguing deficit affecting consciousness but notably the sense of singularity appears to be unaffected.

Split-brain

In a spit-brain, the corpus callosum is surgically severed leading to mostly independent processing in the right and the left hemispheres. This naturally evokes the idea that each hemisphere gives rise to an independent conscious agent, and indeed early studies claimed to have found evidence for this (Gazzaniga, 1967; Sperry, 1968, 1984). These studies suggested that independent perceptual processing and independently generated responses within each hemisphere.

However, where the former claim of independent perceptual processing has stood up to the test, the latter claim of independently generated responses has been discredited across a range of patients and tasks (Clarke & Zaidel, 1989; Corballis, Corballis, Fabri, Paggi, & Manzoni, 2005; de Haan, Fabri, et al., 2020; Pinto, Lamme, & de Haan, 2017; Pinto, Neville, et al., 2017; Trevarthen and Sperry, 1973). This has rekindled the debate of whether the self is split in split-brain patients (Corballis, Corballis, Berlucchi, & Marzi, 2018; de Haan, Fabri, et al., 2020; Pinto, Lamme, et al., 2017; Pinto, Neville, et al., 2017; Volz & Gazzaniga, 2017; Volz et al., 2018). Note furthermore that despite the widespread claims of a split self in split-brain patients, these patients seem to behave in a socially ordinary manner and they report feeling unchanged after the operation (Bogen, Fisher, & Vogel, 1965; Pinto, Neville, et al., 2017; Sperry, 1968, 1984).

A second observation is crucial here. Split-brain patients appear unaware of their split perception. In a normal situation, that is perhaps not that strange as both hemispheres are fully informed when the patient moves his head and eyes, but then again, it should be obvious that when they stare straight ahead each hemisphere has a hemianopia. One intriguing way to explain this is that it is normal to experience many separate parallel conscious experiences. In a sense, healthy subjects may also have separate processing of the visual half fields. The subjective experience in healthy subjects is that they view coherently integrated full fields. This could be because they have a corpus callosum that supports this integration or it could be the case that we experience these as separate but simultaneous conscious experiences.

Impairments in the sense of singularity

If our hypothesis is correct, then one could expect that in certain patients with brain dysfunction the feeling of singularity has been disrupted. Note that the issue here is not impaired levels of consciousness but deficits of experiencing the singularity. It is not immediately obvious what such a singularity deficit would look like but it is clear that it would be a subjective experience involving feelings such as loss of unity, loss of self, and loss of agency. These problems are not often reported in the neurological literature, but there are notable references in other areas, such as in psychiatry and psycho-active drugs.

Schizophrenia

Bleuler had already suggested that disintegration of the 'self' is a central symptom of schizophrenia: 'Ganz intakt ist dennoch das Ich nirgends' (Bleuler, 1911: p. 58). Ipseity is a term from the Latin 'ipse' meaning 'self' or 'itself'. In psychiatry, the term refers to a crucial sense of being with an automatic 'mineness' of experience (Sass & Parnas, 2003). Sass, Pienkos, Nelson, and Medford (2013) continue to suggest that deficits of ipseity have two related aspects. First, 'hyper-reflexivity' refers to an exaggerated self-consciousness. It involves an alienating attention to 'automatic popping-up or popping-out of phenomena and processes that would normally remain in the tacit background of awareness'. This description does not reflect the idea of a disturbance of singularity. However, the second aspect, 'diminished self-affection', is conceptualized as 'a reduction in the very sense of existing as an aware subject or agent of action, that is, to a diminished sense of existing as a first-person perspective on the world, an experiencing entity'. Reviewing the psychiatric literature on schizophrenia, they conclude that ipseity problems occur frequently in this population. Feinberg and Keenan (2005) specifically looked at patients with delusional mis-identification syndrome, such as the Capgras and Fregoli syndrome, and suggested that a loss of self is central to these neuropsychiatric conditions. Interestingly, these patients often show damage to frontal regions in addition to right hemisphere lesions.

Depersonalization

Depersonalization disorder is described as a dissociative disorder entailing 'a feeling of detachment or estrangement from one's self' (DSM IV, 2000). The symptoms involve emotional numbing, loss of sense of agency, and altered experience of the body, time, and space (e.g., Simeon & Abugel, 2006). This description is, at least, reminiscent of a problem in singularity. Interesting are the early observations by Hughlings Jackson who was one of the first to propose a theory of the self. He described it as a double phenomenon with a subject and object allowing for the emergence of 'introspection of consciousness'. The experience of the Self was reliant on evolutionary new brain structures, specifically the prefrontal cortex. He predicted on the basis of his experience with epileptic patients that the self could be lost as a result of brain dysfunction leading to depersonalization and a diminution of the sense of 'me-ness' (Meares, 1999).

Depersonalization is usually reported in psychiatric patients suffering from either depression or anxiety. However, several reports have documented depersonalization and derealization symptoms in patients with epilepsy (Medford, Sierra, Stringaris, Brammer, and David, 2016). Heydrich, Marillier, Evans, Seeck, and Blanke (2019) suggested that it was patients with the epileptogenic zone in the dorsal premotor cortex that experienced ictal depersonalization with altered self-identification, while patients with derealization suffered from temporal lobe epilepsy. They describe the depersonalization disorder as 'a

disturbing change in the quality of first-person experience, almost invariably encompassing a diminished sense of self and an alteration in emotional experience such that the sufferer feels less emotionally reactive, with emotions experienced as decreased or damped down'. In their view, the attenuation of emotional experience was associated with reduced activity of the insula. This raises again the interesting hypothesis that the parieto-frontal singularity network is closely affiliated with the insula. It is, in this context, interesting that Craig (2009, 2011) has suggested that the anterior insula entails a re-representation of interoception that serves as the platform involved in subjective feelings and, as such, plays a pivotal role in awareness. In his model, the limbic system, entailing the motor cortex, the anterior cingulate, and medial prefrontal cortex, works together with the limbic sensory cortex, that is, the anterior insula. In our hypothesis, the role of this network is slightly rephrased in that it is responsible for the feeling of singular meness, that is, of the singularity. See also Seth, Suzuki, and Critchley (2012) for a predictive coding account of conscious presence in which the insula is a central neuroanatomical structure.

Psycho-active drugs

According to Milliére (2017), there are three neuropharmacological classes of drugs that can induce 'ego dissolution': classical psychedelics, dissociative anaesthetics, and agonists of the kappa opioid receptor. These drugs operate on different neurotransmitter receptors, and they all share a strong subjective effect on the subjective experience of the self, including ego dissolution. It is well known that these drugs may distort perception and mood (e.g., Halberstadt, 2015) with smaller doses but the more complex effects at higher doses have received less attention. Some of these hallucinogenic drugs may cause distortions of self-consciousness that have been described as a dramatic breakdown of the sense of self or 'ego dissolution'. Mescaline is both a notable and famous example, as illustrated by Aldous Huxley who portrayed his experience with mescaline as the 'final stage of egolessness' (Huxley, 1954). Drugs that may produce similar effects are LSD and psilocybin. Dissociative anaesthetics constitute another group of psycho-active substances that been associated with ego dissolution experiences. These anaesthetics, such as ketamine and dextromethorphan, target the NMDA receptors as antagonists. In a recent review, Sleigh, Warnaby, and Tracey (2018) conclude that fMRI and EEG studies comparing the effect of sleep and general anaesthesia on consciousness and 'self-' related functions have shown critical differences. They point to the drug-induced reduction of anterior insula function that is absent in sleep. With increasing levels of anaesthetics, patients often become depersonalized and may lose their sense of agency, while higher-order functions and a disembodied self-awareness may be retained. In contrast, during sleep the loss of agency and sentience parallels or lags behind, the decrease in self-awareness. Finally, Milliére (2017) identifies kappa opioid agonists, such as salvinorin-A, the active ingredient in the Mexican plant *Salvia divinorum*, as the third compound to provoke alterations in self-awareness and depersonalization-like feelings. It triggers fewer visual distortions but may induce intense somatic effects and feelings of losing a sense of bodily ownership.

Loss of Self-activation

The 'loss of psychic self-activation' or 'psychic akinesia' syndrome was first described by Laplane, Baulac, Widlocher, and Dubois (1984) in patients suffering from carbon

monoxide intoxication or wasp stings. It is characterized by a 'striking reduction in spontaneous motion and speech, almost complete lack of initiative, absence of spontaneous mental activation of any kind, subjective "mental emptiness", loss of interest for previously motivating activities, and apparent emotional flatness or poor expressiveness of affect' (Riveros et al., 2019). A case study with a patient who suffered from severe loss of psychic self-activation after a post-anoxic coma extensive neuroimaging including CT, MRI, and SPECT showed bilateral damage to the basal ganglia and prefrontal hypoperfusion. The suggestion that the basal ganglia (and notably the antero-dorsal part of the striatum) might be involved in the maintenance of the self supports the proposals by Morsella et al. (2016).

Taken these neuropsychological observations together, we propose that the processes that impose singularity on the interaction between intentions of the whole organism and the environment are carried out by a network involving subcortical structures, such as the striatum and the thalamus, the medial prefrontal cortex, and the anterior insula.

Resting state imaging in a split-brain patient

Healthy subjects in rest have a number of stable brain networks that are co-activated over time (Smith et al., 2009). These networks are of particular interested when considering the functional organization of split-brain patients because they entail, for eight out of 10 networks, bilateral components. For this reason, we tested the split-brain patient DDC to evaluate to what degree the bilateral nature of these components is dependent on a functioning corpus callosum, using BOLD-MRI. DDC has had a complete removal of the corpus callosum and most of the anterior commissure to help relieve epileptic seizures. Other than the removal of the corpus callosum and most of the anterior commissure, the patient had no brain damage, and fell within the normal IQ range. See Pizzini et al. (2010) and Corballis et al. (2010) for a detailed description of this patient.

The MR scanner and recording procedures and sequence parameters were identical to the functional imaging of Fabri & Polonara, 2013, with the following exception: We recorded two runs of functional data, each consisting of 300 volumes. During the recording of each of these runs, we first showed a movie that lasted for 480 s (160 volumes), while the subject was instructed to relax during the remainder of the run (420 s, 140 volumes). Pre-processing of BOLD-MRI data was identical to Groen et al., 2018, and subsequently, both runs were denoised using FSL-Fix (Griffanti et al., 2014). Next, we performed a concatenated ICA (Beckmann & Smith, 2004) analysis on the 2 x 420 s of BOLD-MRI data in which no movie was presented. This yielded 41 components of which we calculated the dice scores (threshold $t > 1.7$) in relation to the 10 resting state components from Smith et al., 2009. The seven components that overlapped between these two data sets are displayed in Figure 1. This overlap is substantial for all components of DCC except 5 and 6 (see Table 1). Two components observed in DDC overlapped with multiple components from Smith et al., 2009. Next, we determined to what degree the unilateral activations within each hemisphere were symmetrical by flipping the slices of one hemisphere around the central sagittal axis onto the other hemisphere, and calculating the correlations between the two hemispheres. This analysis indicated substantial symmetry in the activation of left and right hemisphere for five of the seven components (see Table 1).

These results strongly indicate that there is, for at least four components, coherence of activation across the two hemispheres of the brain that are not dependent on the corpus callosum. By exclusion, it can be deduced that this coherence is the result of subcortical

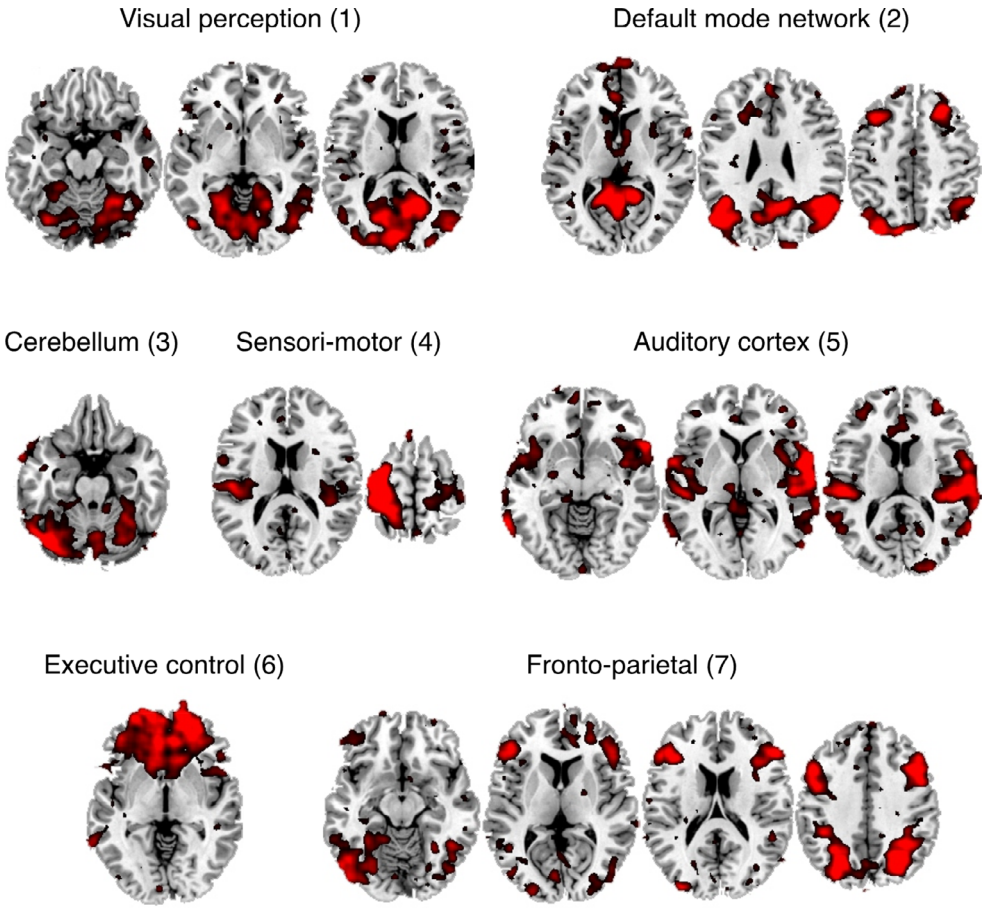

Figure 1. The seven components that overlapped between (Smith et al., 2009) and the components from the split-brain patient (threshold at $z > 1.7$). The numbers between the brackets indicate the overlap with the components of Smith et al. (2009). [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1. Correlations between right and left hemisphere activations and dice scores in the 10 resting states components in normal subjects (Smith et al., 2009) and the seven in the split-brain patient DCC.

SB Comp	L-R Comp	RS Comp	Dice Score
1	0.46	1	0.22
		2	0.15
		3	0.19
2	0.48	4	0.18
3	0.19	5	0.1
4	0.21	6	0.14
5	0.35	7	0.17
6	0.55	8	0.16
7	0.45	9	0.14
		10	0.17

processes. In our view, this is the subcortical aspect of the system that formulates our intentions and develops action plans that concern a single body in an external world that sets continuously changing constraints. As suggested above, this system is, typically, single because, although there are many different input channels signalling different aspects of the outside world and many response possibilities, there is only one body in one environment. Therefore, although consciousness may be distributed, especially sensory/visual consciousness, the sense of singularity may be unaffected in a split-brain patient due to coherence driven by the singular intentional system.

Conclusion

In this paper, we have argued for the idea that conscious awareness is distributed, and experienced locally. We suggest that the subjective feeling of singularity is independent of these.

Following this reasoning, we predict that there should be many seats for different types of conscious experience but that the hardware related to the subjective feeling of singularity is located in the system involved with action planning and intentions. Crucially, we see this seat of singularity not as a meta-system curating experiences but as a system that arises in our interactions with the outside world.

To make this point, we review data from neuropsychology showing that the loss of a function does not need to coincide with awareness about this loss (anosognosia), that subjects can have local awareness deficits without altering their sense of singularity (see the section on knowledge without experience), that subjects can have both (neglect), and that subjects in which the connectivity is fundamentally altered (split-brain) still do not experience an altered sense of singularity. Moreover, the sense of singularity may only come into existence due to environmental *response* constraints.

We support the idea with novel results in which we evaluate bilateral connectivity in a split-brain patient. We show that, using independent component analysis, our high-functioning split-brain patient has a substantial number of components with normal bilateral activation.

While brain damage seems to alter local consciousness, but not singularity the opposite occurs in a range of psychiatric disorders like schizophrenia, depersonalization but also psycho-active drugs. We believe these double dissociations over phenomena further support our idea that singularity and conscious awareness are fundamentally different and that the sense of singularity can coexist with several disunified conscious processes, both in patients and healthy adults.

Our concept of a system involved in singularity differs from global workspace theory (Dehaene & Naccache, 2001) in the sense that we believe these systems are (largely) independent from each other, and the latter not being the supervisor of the earlier. Furthermore, the results from our split-brain patient argue against IIT (Tononi & Koch, 2015), in that a substantial drop in connectivity (removal of corpus callosum + anterior commissure) does not result in a drop of global consciousness. If anything our results are in line with recurrent processing theory (Lamme, 2006) although this theory (or any of the other ones) does not addresses the sense of singularity.

In sum, we have argued that the experience of singularity and conscious awareness are fundamentally different and that the sense of singularity can coexist with several disunified conscious processes, both in patients and healthy adults.

Acknowledgements

This work was supported by an ERC Advanced grant FAB4V (#339374) to Edward de Haan and a Templeton grant (ID# 61382) 'Towards understanding a unified mind') to YP.

Conflicts of interest

All authors declare no conflict of interest.

Author contributions

Edward H. F. de Haan, Ph.D. (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Writing – original draft; Writing – review & editing) H. Steven Scholte (Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – original draft) Yair Pinto (Conceptualization; Investigation; Methodology; Supervision; Writing – original draft; Writing – review & editing) Nicoletta Foschi (Conceptualization; Investigation; Project administration; Resources; Writing – original draft) Gabriele Polonara (Conceptualization; Investigation; Methodology; Project administration; Resources; Writing – original draft) Mara Fabri (Conceptualization; Investigation; Methodology; Project administration; Resources; Writing – original draft).

References

Alvarez, G. A., & Cavanagh, P. (2005). Independent resources for attentional tracking in the left and right visual hemifields. *Psychological Science*, *16*, 637–643. https://doi.org/10.1111/j.1467-9280.2005.01587.x

Anton, G. (1899). Ueber die Selbstwahrnemung der Herderkrankungen des Gehirns durch den Kranken bei Rindenblindheit und Rindentaubheit. *Archiv Fir Psychiatric Und Nervenkrankheiten*, *32*, 86–127.

Baars, B.J. (1988). *A cognitive theory of consciousness*. Cambridge, UK: Cambridge University Press.

Baars, B. J. (2005). Global workspace theory of consciousness: Toward a cognitive neuroscience of human experience. *Progress in Brain Research*, *150*, 45–53. https://doi.org/10.1016/S0079-6123(05)50004-9

Babinski, M. J. (1914). Contribution a l'etude des troubles mentaux dans l'hemiplegie organique cerebrale (Anosognosie). *Revue Neurologique*, *12*, 845–848.

Bauer, R. M. (1984). Autonomic recognition of names and faces in prosopagnosia: A neuropsychological application of the guilty knowledge test. *Neuropsychologia*, *22*, 457–469. https://doi.org/10.1016/0028-3932(84)90040-x

Bayne, T. (2008). The unity of consciousness and the split-brain syndrome. *The Journal of Philosophy*, *105*, 277–300. https://doi.org/10.2307/20620103

Bayne, T. (2010). *The unity of consciousness*. Oxford, UK: Oxford University Press.

Bayne, T., & Chalmers, D. J. (2003). What is the unity of consciousness? In A. Cleeremans (Ed.), *The unity of consciousness: Binding, integration and dissociation* (pp. 23–58). Oxford, UK: Oxford University Press.

Beckmann, C. F., & Smith, S. M. (2004). Probabilistic independent component analysis for functional magnetic resonance imaging. *IEEE Transactions on Medical Imaging*, *23*(2), 137–152. https://doi.org/10.1109/TMI.2003.822821

Berti, A., & Rizzolatti, G. (1992). Visual Processing without awareness: Evidence from unilateral neglect. *Journal of Cognitive Neuroscience*, *4*, 345–351. https://doi.org/10.1162/jocn.1992.4.4.345

Bisiach, E., Vallar, G., Perani, D., Papagno, C., & Berti, A. (1986). Unawareness of disease following lesions of the right hemisphere: Anosognosia for hemiplegia and anosognosia for hemianopia. *Neuropsychologia*, *24*, 471–482. https://doi.org/10.1016/0028-3932(86)90092-8

Bleuler, E. (1911). *Dementia praecox or the group of schizophrenias* (J Zinkin, Trans.). New York, NY: International Universities Press.

Block, N. (2007). Consciousness, accessibility, and the mesh between psychology and neuroscience. *The Behavioral and Brain Sciences*, *30*, 481–499. https://doi.org/10.1017/S0140525X07002786

Bodamer, J. (1947). Die prosopagnosie. *Arch Psychiatr. Nervenkr*, *179*, 6–53.

Bogen, J. E., Fisher, E., & Vogel, P. (1965). Cerebral commissurotomy: A second case report. *JAMA*, *194*(12), 1328–1329.

Broadbent, D. E. (1958). *Perception and communication*. London, UK: Pergamon.

Campion, J., Latto, R., & Smith, Y. M. (1983). Is blindsight an effect of scattered light, spared cortex, and near-threshold vision? *Behavioral Brain Sciences*, *3*, 423–486.

Cavanagh, P., & Alvarez, G. A. (2005) Tracking multiple targets with multifocal attention. *Trends in Cognitive Science*, *9*, 349–354. https://doi.org/10.1016/j.tics.2005.05.009

Clarke, J. M., & Zaidel, E. (1989). Simple reaction times to lateralized light flashes. Varieties of interhemispheric communication routes. *Brain*, *112*, 849–870. https://doi.org/10.1093/brain/112.4.849

Corballis, M. C., Birse, K., Paggi, A., Manzoni, T., Pierpaoli, C., & Fabri, M. (2010). Mirror-image discrimination and reversal in the disconnected hemispheres. *Neuropsychologia*, *48*, 1664–1669.

Corballis, M. C., Corballis, P. M., Berlucchi, G., & Marzi, C. A. (2018). Perceptual unity in the split brain: The role of subcortical connections. *Brain*, *141*(6), e46. https://doi.org/10.1093/brain/awy085

Corballis, M. C., Corballis, P. M., Fabri, M., Paggi, A., & Manzoni, T. (2005). Now you see it, now you don't: Variable hemineglect in a commissurotomized man. *Cognitive Brain Research*, *25*(2), 521–530. https://doi.org/10.1016/j.cogbrainres.2005.08.002

Coslett, H. B., & Saffran, E. M. (1990). Evidence for preserved reading in "pure" alexia. *Brain*, *112*: 327–359. https://doi.org/10.1093/brain/112.2.327

Cowey, A. (2010). The blindsight saga. *Experimental Brain Research*, *200*, 3–24. https://doi.org/10.1007/s00221-009-1914-2

Craig, A. D. (2009). How do you feel - now? The anterior insula and human awareness. *Nature Review Neuroscience*, *10*, 59–70. https://doi.org/10.1038/nrn2555

Craig, A. D. (2011). Significance of the insula for the evolution of human awareness of feelings from the body. *Annals of the New York Academy of Sciences*, *1225*, 72–82. https://doi.org/10.1111/j.1749-6632.2011.05990.x

Critchley, M. (1949). The problem of awareness or non-awareness of hemianopic field defects. *Transactions of the Ophthalmological Society UK*, *69*, 95–109.

Danckert, J., & Rossetti, Y. (2005). Blindsight in action: What can the different sub-types of blindsight tell us about the control of visually guided actions?" *Neuroscience and Biobehavioral Reviews*, *29*, 1035–1046. https://doi.org/10.1016/j.neubiorev.2005.02.001

David, A. S., Bedford, N., Wiffen, B., & Gilleen, J. (2012). Failures of metacognition and lack of insight in neuropsychiatric disorders. *Philosophical Transactions of the Royal Society B*, *367*, 1379–1390. https://doi.org/10.1098/rstb.2012.0002

de Haan, E. H. F. (2017) Prosopagnosia. In R. Stein (Ed.). *Neuroscience and Biobehavioral Psychology*. New York, NY: Elseviers Science. https://doi.org/10.1016/B978-0-12-809324-5.03150-3

de Haan, E. H. F. (2019). *Impaired vision: How the visual world may change after brain damage*. New York, NY: Wiley-Blackwell.

de Haan, E. H. F., Bauer, R. M., & Greve, K. W. (1992). Behavioural and Psychophysiological evidence for covert face recognition in a prosopagnosic patient. *Cortex*, *28*, 77–95. https://doi.org/10.1016/s0010-9452(13)80167-0

de Haan, E. H., Fabri, M., Dijkerman, H. C., Foschi, N., Lattanzi, S., & Pinto, Y. (2020). Unified tactile detection and localisation in split-brain patients. *Cortex*, *124*, 217–223. https://doi.org/10.1016/j.cortex.2019.11.010

de Haan, E. H. F., Young, A. W., & Newcombe, F. (1987). Face recognition without awareness. *Cognitive Neuropsychology*, *4*, 385–415. https://doi.org/10.1016/0278-2626(90)90056-t

de Renzi, E. (1986). Prosopagnosia in two patients with CT scan evidence of damage confined to the right hemisphere. *Neuropsychologia*, *24*(3), 385–389. https://doi.org/10.1016/0028-3932(86)90023-0

de Vries, J., & Ward, L. M. (2016). An "ecological" action-based synthesis. *Behavioural and Brain Sciences*, https://doi.org/10.1017/S0140525X15002046, e173.

Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition*, *79*, 1–37. https://doi.org/10.1016/s0010-0277(00)00123-2

Drew, T., Mance, I., Horowitz, T. S., Wolfe, J. M., & Vogel, E. K. (2014). A soft handoff of attention between cerebral hemispheres. *Current Biology*, *24*, 1133–1137. https://doi.org/10.1016/j.cub.2017.11.076

Fabri, M., & Polonara, G. (2013). Functional topography of human corpus callosum: An FMRI mapping study. *Neural Plasticity*, *2013*, 251308. https://doi.org/10.1155/2013/251308

Feinberg, T. E., & Keenan, J. P. (2005). Where in the brain is the self? *Consciousness and Cognition*, *14*, 661–678. https://doi.org/10.1016/j.concog.2005.01.002

Gazzaniga, M. S. (1967). The split brain in man. *Scientific American*, *217*, 24–29.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *11*, 501–518. https://doi.org/10.1037//0278-7393.11.3.501

Griffanti, L., Salimi-Khorshidi, G., Beckmann, C.F., Auerbach, E. J., Douaud, G., Sexton, C. E., … Smith, S. M. (2014). ICA-based artefact removal and accelerated fMRI acquisition for improved resting state network imaging. *NeuroImage*, *95*, 232–247. https://doi.org/10.1016/j.neuroimage.2014.03.034

Groen, I. I., Jahfari, S., Seijdel, N., Ghebreab, S., Lamme, V. A., & Scholte, H. S. (2018). Scene complexity modulates degree of feedback activity during object detection in natural scenes. *PLoS Computational Biology*, *14*(12), e1006690. https://doi.org/10.1371/journal.pcbi.1006690

Halberstadt, A. L. (2015). Recent advances in the neuropsychopharmacology of serotonergic hallucinogens. *Behavioral Brain Research*, *277*, 99–120. https://doi.org/10.1016/j.bbr.2014.07.016

Halligan, P. W., Marshall, J. C., & Wade, D. T. (1989). Visuospatial neglect: underlying factors and test sensitivity. *Lancet*, *2*, 908–911. https://doi.org/10.1016/s0140-6736(89)91561-4

Heilman, K. M., Valenstein, E., & Watson, R. T. (2000). Neglect and related disorders. *Seminars in Neurology*, *20*, 463–470. https://doi.org/10.1055/s-2000-13179

Heilman, K. M., Watson, R. T., & Valenstein, E. (1985) Neglect. In: K. M. Heilman, & E. Valenstein (Eds.), *Clinical neuropsychology* (pp. 243–293). Oxford, UK: Oxford University Press. New York,.

Heydrich, L., Marillier, G., Evans, N., Seeck, M., & Blanke, O. (2019). Depersonalization- and derealization-like phenomena of epileptic origin. *Annals of Clinical and Translational Neurology*, *6*, 1739–1747. https://doi.org/10.1002/acn3.50870

Huxley, A. (1954). *The doors of perception and heaven and hell*. London, UK: Harper Collins Publishers.

Korsakoff, S. (1889). Etude medico-psychologie sur une forme des maladies de la memoire. *Revue Philosophique*, *5*, 501–530.

Lamme, V. A. (2006). Towards a true neural stance on consciousness. *Trends Cognitive Science (regul. Ed.,) 10*, 494–501. https://doi.org/10.1016/j.tics.2006.09.001

Lamme, V. A., & Roelfsema, P. R. (2000). The distinct modes of vision offered by feedforward and recurrent processing. *Trends in Neuroscience*, *23*, 571–579. https://doi.org/10.1016/s0166-2236(00)01657-x

Laplane, D., Baulac, M., Widlocher, D., & Dubois, B. (1984). Pure psychic akinesia with bilateral lesions of basal ganglia. *Journal of Neurology, Neurosurgery and Psychiatry*, *47*, 377–385. https://doi.org/10.1136/jnnp.47.4.377

Lebrun, Y. (1987). Anosognosia in aphasics. *Cortex*, *23*(2), 251–263. https://doi.org/10.1016/s0010-9452(87)80035-7

Lunven, N., Thiebaut De Schotten, M., Bourlon, C., Duret, C., Migliaccio, R., Rode, G., & Bartolomeo, P. (2015). White matter lesional predictors of chronic visual neglect: a longitudinal study. *Brain*, *138*, 746–760. https://doi.org/10.1093/brain/awu389

McGlynn, S. M., & Schacter, D. L. (1989). Unawareness of deficits in neuropsychological syndromes. *Journal of Clinical and Experimental Neuropsychology*, *11*, 143–205. https://doi.org/10.1080/01688638908400882

Meares, R. (1999). The contribution of hughlings jackson to an understanding of dissociation. *American Journal of Psychiatry*, *156*, 1850–1855. https://doi.org/10.1176/ajp.156.12.1850

Medford, N., Sierra, M., Stringaris, A. G.,Brammer, M. J., & David, A. S. (2016). Emotional experience and awareness of self: Functional MRI studies of depersonalization disorder. *Frontiers in Psychology*, *7*, 432. https://doi.org/10.3389/fpsyg.2016.00432

Millière, R. (2017). Looking for the self: Phenomenology, neurophysiology and philosophical significance of drug-induced ego dissolution. *Frontiers in Human Neuroscience*, *11*, 245. https://doi.org/10.3389/fnhum.2017.00245

Milner, B. (1962) *Physiologie de l'hippocampe*. P. Passouant (Ed.), (pp. 257–272). Paris, France: Centre National de la Recherche Scientifiqu.

Morsella, E., Godwin, C. A., Jantz, T., Krieger, S. C., & Gazzaley, A. (2016). Homing in on consciousness in the nervous system: An action-based synthesis. *Behavioral and Brain Sciences*, *39*, 1–70. https://doi.org/10.1017/S0140525X15000643, e168.

Neisser, U., & Becklen, R. (1975). Selective looking: Attending to visually specified events. *Cognitive Psychology*, *7*, 480–494.

Parkin, A. J., Miller, J., & Vincent, R. (1987). Multiple neuropsychological deficits due to anoxic encephalopathy: A case study. *Cortex*, *23*(4), 655–665. https://doi.org/10.1016/s0010-9452(87)80055-2

Pinto, Y., Lamme, V. A., & de Haan, E. H. (2017). Cross-cueing cannot explain unified control in split-brain patients. *Brain*, *140*(11):e68. https://doi.org/10.1093/brain/awx235

Pinto, Y., Neville, D. A., Otten, M., Corballis, P. M., Lamme, V. A., de Haan, E. H., . . . de Haan, E. H. F. (2017). Split brain: Divided perception but undivided consciousness. *Brain*, *140*, 1231–1237. https://doi.org/10.1093/brain/aww358

Pizzini, F., Polonara, G., Mascioli, G., Beltramello, A., Foroni, R., Paggi, A., . . . Fabri, M. (2010). Diffusion tensor tracking of callosal fibers several years after callosotomy. *Brain Research*, *1312*, 10–17.

Pöppel, E., Held, R., & Frost, D. (1973). Residual visual function after brain wounds involving the central visual pathways in man. *Nature*, *243*, 295–296.

Renault, B., Signoret, J. L., Debruille, B., Breton, F., & Bolgert, F. (1989). Brain potentials reveal covert facial recognition in prosopagnosia. *Neuropsychologia*, *27*, 905–912. https://doi.org/10.1016/0028-3932(89)90066-3

Riveros, R., Bakchine, S., Pillon, B., Poupon, F., Miranda, M., & Slachevsky, A. (2019). Fronto-subcortical circuits for cognition and motivation: Dissociated recovery in a case of loss of psychic self-activation. *Frontiers in Psychology*, *9*, 2781. https://doi.org/10.3389/fpsyg.2018.02781

Rizzo, M., Hurtig, R., & Damasio, A. R. (1987). The role of scanpaths in facial recognition and learning. *Annals of Neurology*, *22*, 41–45. https://doi.org/10.1002/ana.410220111

Sanders, M. D., Warrington, E. K., Marshall, J., & Weiskrantz, L. (1974). 'Blindsight': Vision in a field defect. *Lancet*, *1*, 707–708. https://doi.org/10.1016/s0140-6736(74)92907-9

Sasai, S., Boly, M., Mensen, A., & Tononi, G. (2016). Functional split brain in a driving/ listening paradigm. *Proceedings of the National Academy of Sciences of the United States of America*, *113*, 14444–14449. https://doi.org/10.1073/pnas.1613200113

Sass, L. A., & Parnas, J. (2003). Schizophrenia, consciousness, and the self. *Schizophrenia Bulletin*, *29*, 427–444. https://doi.org/10.1093/oxfordjournals.schbul.a007017

Sass, L., Pienkos, E., Nelson, B., & Medford, N. (2013). Anomalous self-experience in depersonalization and schizophrenia: A comparative investigation. *Consciousness and Cognition*, *22*, 430–441. https://doi.org/10.1016/j.concog.2013.01.009

Schacter, D. L. (1989). On the relation between memory and consciousness: dissociable interactions and conscious experience. In H. L. Roediger & F. I. M. Carik (Eds.), *Varieties of memory and consciousness: essays in honour of endel tulving* (pp. 355–389). Hillsdale, NJ: Lawrence Erlbaum.

Schacter, D. (2020) Implicit memory, constructive memory, and imagining the future: A career perspective. *Perspectives on Psychological Science*, *14*, 256–272. https://doi.org/10.1177/1745691618803640

Schacter, D., Alpert, N. M., Savage, C. R., Rauch, S. L., & Albert, M. S. (1996). Conscious recollection and the human hippocampal formation: Evidence from positron emission tomography. *Proceedings of the National Academy of Sciences USA*, *93*, 321–325. https://doi.org/10.1073/pnas.93.1.321

Schacter, D. L., McAndrews, M. P., & Moscovitch, M. (1988). Access to consciousness: Dissociations between implicit and explicit knowledge in neuropsychological syndromes. In L. Weiskrantz (Ed.), *Thought without language* (pp. 242–278). Oxford, UK: Oxford University Press.

Seth, A. K., Suzuki, K., & Critchley, H. D. (2012). An interoceptive predictive coding model of conscious presence. *Frontiers in Psychology*, *2*, 395. https://doi.org/10.3389/fpsyg.2011.00395

Shallice, T., & Saffran, E. (1986). Lexical processing in the absence of explicit word recognition: Evidence from a letter-by-letter reader. *Cognitive Neuropsychology*, *3*, 429–458.

Simeon, D., & Abugel, J. (2006). *Feeling unreal: Depersonalization disorder and the loss of self*. New York, NY: Oxford University Press.

Sleigh, J., Warnaby, C., & Tracey, I. (2018). General anaesthesia as fragmentation of selfhood: Insights from electroencephalography and neuroimaging. *British Journal of Anaesthesia*, *121* (1), 233e240. https://doi.org/10.1016/j.bja.2017.12.038

Smith, S. M., Fox, P. T., Miller, K. L., Glahn, D. C., Fox, P. M., Mackay, C. E., . . . Beckmann, C. F. (2009). Correspondence of the brain's functional architecture during activation and rest. *Proceedings of the National Academy of Sciences*, *106*, 13040–13045. https://doi.org/10.1073/pnas.0905267106

Smits, A. R., Seijdel, N., Scholte, H. S., Kentridge, R. W., Heywood, C. A., & de Haan, E. H. F. (2019). Action blindsight and antipointing in a hemianopic patient. *Neuropsychologia*, *128*, 270–275. https://doi.org/10.1016/j.neuropsychologia.2018.03.029

Solcà, M., Guggisberg, A. G., Schnider, A., & Leemann, B. (2015). Facial blindsight. *Frontiers Human Neuroscience*, *9*, 522. https://doi.org/10.3389/fnhum.2015.00522

Sperry, R. W. (1968). Hemisphere deconnection and unity in conscious awareness. *American Psychologist*, *23*, 723.

Sperry, R. (1984). Consciousness, personal identity and the divided brain. *Neuropsychologia*, *22*(6), 661–673. https://doi.org/10.1016/0028-3932(84)90093-9

Squire, L. R. (2009). The legacy of patient H.M. for neuroscience. *Neuron*, *61*, 6–9. https://doi.org/10.1016/j.neuron.2008.12.023

Stoerig, P., & Cowey, A. (1992). Wavelength discrimination in blindsight. *Brain*, *115*, 425–444. https://doi.org/10.1093/brain/115.2.425

Talland, G. A. (1961). Confabulation in the Wernicke-Korsakoff syndrome. *Journal of Nervous and Mental Disease*, *132*, 361–381.

Talland, G. A. (1965). *Deranged memory*. New York, NY: Academic Press.

Tamietto, M., & Morrone, M. C. (2016). Visual plasticity: Blindsight bridges anatomy and function in the visual system. *Current Biology*, *26*, R70–R73. https://doi.org/10.1016/j.cub.2015.11.026

Tononi, G. (2004). An information integration theory of consciousness. *BMC Neuroscience*, *5*, 42. https://doi.org/10.1038/nrn.2016.44

Tononi, G. (2005). Consciousness, information integration, and the brain. *Progress in Brain Research*, *150*, 109–126. https://doi.org/10.1016/S0079-6123(05)50009-8

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

Trevarthen, C., & Sperry, R. W. (1973). Perceptual unity of the ambient visual system in human commissurotomy patients. *Brain*, *96*, 547–570.

Trevethan, C. T., Sahraie, A., & Weiskrantz, L. (2007). Form discrimination in a case of blindsight. *Neuropsychologia*, *45*, 2092–2103. https://doi.org/10.1016/j.neuropsychologia.2007.01.022

Volz, L. J., & Gazzaniga, M. S. (2017). Interaction in isolation: 50 years of insights from split-brain research. *Brain*, *140*, 2051–2060. https://doi.org/10.1093/brain/awx139

Volz, L. J., Hillyard, S. A., Miller, M. B., & Gazzaniga, M. S. (2018). Unifying control over the body: Consciousness and cross-cueing in split-brain patients. *Brain*, *141*(3), e15. https://doi.org/10.1093/brain/awx359

von Monakow, C. (1885). Experimentelle und pathologisch-anatomische Untersuchungen über die Beziehung der sogenannten Sehspäre zu den infracortikalen Opticuszentren und zum N. opticus (II). *Archiv Fur Psychiatrie Und Nervenkrankheiten*, *16*, 151–199.

Warrington, E. K., & Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature*, *217*, 972–974.

Weiskrantz, L. (1998). Consciousness and commentaries. In S. R. Hameroff, A. W. Kaszniak & A. C. Scott (Eds.), *Towards a science of consciousness II—the second tucson discussions and debates* (pp. 371–377). Cambridge, MA: MIT Press.

Weiskrantz, L. (1999). *Consciousness lost and found: A neuropsychological exploration*. Oxford, UK: OUP.

Weiskrantz, L. (2009). *Blindsight: A case study spanning 35 years and new developments* (3rd ed.). Oxford, UK: Oxford University Press.

Weiskrantz, L., Warrington, E. K., Sanders, M. D., & Marshall, J. (1974). Visual capacity in the hemianopic Weld following a restricted cortical ablation. *Brain*, *97*, 709–728.

Wernicke, C. (1874). *Der aphasische Symptomencomplex: eine psychologische Studie auf anatomischer Basis*. Breslau: Cohn & Weigert.

Yantis, S., & Johnston, J. C. (1990). On the locus of visual selection: Evidence from focused attention tasks. *Journal of Experimental Psychology: Human Perception and Performance*, *16*(1), 135–149. https://doi.org/10.1037//0096-1523.16.1.135

Young, A. W., & de Haan, E. H. F. (1988). Boundaries of covert recognition in prosopagnosia. *Cognitive Neuropsychology*, *5*, 317–336.

Young, A. W., de Haan, E. H. F., & Newcombe, F. (1990). Unawareness of impaired face recognition. *Brain and Cognition*, *14*, 1–18. https://doi.org/10.1016/0278-2626(90)90056-t

Young, A. W., Hellawell, D., & de Haan, E. H. F. (1988). Cross domain semantic priming in normal subjects and a prosopagnosic patient. *Quarterly Journal of Experimental Psychology*, *40A*, 561–580. https://doi.org/10.1080/02724988843000087

Young, A. W., Newcombe, F., Hellawell, D., & de Haan, E. H. F. (1989). Implicit access to semantic information. *Brain and Cognition*, *11*, 186–209. https://doi.org/10.1016/0278-2626(89)90017-1

Received 19 June 2020; revised version received 22 October 2020