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REVIEWS

Opinion

Are There Islands of Awareness?

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Ordinary human experience is embedded in a web of causal relations that link the brain to the body and the wider environment. However, there might be conditions in which brain activity supports consciousness even when that activity is fully causally isolated from the body and its environment. Such cases would involve what we call islands of awareness: conscious states that are neither shaped by sensory input nor able to be expressed by motor output. This Opinion paper considers conditions in which such islands might occur, including *ex cranio* brains, hemispherotomy, and in cerebral organoids. We examine possible methods for detecting islands of awareness, and consider their implications for ethics and for the nature of consciousness.

Highlights

Awareness may persist in fully disconnected cortical islands.

We identify both natural and artificial examples of potential islands of awareness.

Detecting islands of awareness poses difficult but often addressable challenges.

The possibility of islands of awareness raises important ethical and legal issues.

The discovery of islands of awareness would have important implications for debates about the nature of consciousness.

The Challenge of Islands of Awareness

Consciousness is first and foremost a property of living organisms – organisms that are embodied and embedded in environments. The contents of consciousness are shaped by the sensory stimuli received by the brain, and those contents in turn give rise to behaviours that prompt us to attribute consciousness to an organism. However, there are conscious states in which the transfer of information between the world and the brain is massively reduced, with the result that the brain (or parts thereof) becomes disconnected from its environment. In some conditions, disconnection is partial, so that some form of either input and/or output is retained. In other conditions, the disconnection is complete, so that the brain (or parts thereof) becomes fully isolated from its environment.

What happens to consciousness when the brain becomes disconnected from its environment? Can it support **islands of awareness** (see Glossary), or does consciousness require the presence of (high bandwidth?) interaction between the brain and its environment? This question has long fascinated philosophers, but recent developments in neuroscience, neurosurgery, and neuroengineering now extend the scope of this discussion beyond the philosopher's armchair and out into the laboratory and clinic.

We address three issues raised by the possibility of islands of awareness. The first concerns their nature and distribution. Under what conditions might such islands arise? What forms might they take? How common might they be? A second issue concerns the detection of islands of awareness. Might current methods for detecting consciousness be applicable to islands of awareness, or will we need new tools for identifying consciousness in disconnected brains? A third issue concerns the implications of islands of awareness. What ethical implications might such islands have, and what might they tell us about the nature of consciousness?

We address these issues by considering three conditions in which islands of awareness might be thought to occur: *ex cranio* brains; the neurosurgical procedure of hemispherotomy; and **cerebral organoids**. Although these three cases are by no means the only cases that could be considered here – for example, one might also consider whether islands of awareness could occur *in utero* [1] – we focus on them here because they highlight the issues raised by islands of awareness with particular force and urgency.

From Partial Disconnection to Complete Disconnection

Before we turn to genuine islands of awareness, we begin with cases of merely partial disconnection. Clinical neurology offers a rich repertoire of cases to consider here, for structural lesions can cause the brain to become disconnected on either the input or the output side without loss of consciousness.

Starting from the input side, we know that consciousness can be preserved in the absence of afferent activity from peripheral receptors and nerves. For example, acquired blindness is a condition in which

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patients lose sight but retain the capacity for imagery, visual dreaming, and vivid hallucination [2]. A corresponding dissociation can also occur in audition [3]. We also know that direct cortical stimulation within the appropriate parameters can elicit visual, auditory, tactile, and interoceptive experiences while bypassing subcortical sensory pathways [4] (see also [5] for a recent study in which perceptual discrimination was induced in rodents through optogenetic stimulation of visual cortex). Although we are not aware of any case in which all sensory pathways have been structurally severed without concurrent motor nerve impairment, approximations to a severe multimodal disconnection can occur in the late stages of multiple sclerosis or mitochondrial disorders [6].

On the motor side, a classic example of partial disconnection is locked in syndrome (LIS), which can occur as the result of a ventral pontine lesion severing of all motor fibres except for the third cranial nerve (which drives vertical eye movements and blinking). Despite almost complete motor disconnection, LIS patients can be fully communicative and are undoubtedly conscious. However, in some patients the neurons of the third cranial nerve are also impaired and the patient is unable to produce any detectable motor output [7,8]. In such patients the brain is completely disconnected on the output side, but there is every reason to think that consciousness has been retained despite the loss of even the last channel of motor output.

There are also cases in which the brain becomes disconnected from its environment in both input and output terms, although the disconnection is not always absolute and is often reversible. One form of disconnection occurs in dreaming, when changes in neuromodulation result in cortical gating of sensory inputs and in inhibition of motor neurons [9]. More comprehensive disconnection can occur under the influence of the dissociative anaesthetic ketamine, for at certain doses ketamine blocks both exteroceptive and interoceptive input, allowing patients to undergo invasive surgical procedures. But despite disconnection and profound unresponsiveness ketamine does not always extinguish consciousness, and can instead induce vivid and sometimes terrifying experiences [10].

Although dreaming and ketamine involve consciousness in the context of sensory and motor disconnection, in both cases the disconnection is functional rather than structural. However, reversible disconnection can also result from structural factors. The rare case of a conscious patient in whom concurrent conditions resulted in complete sensory (visual, auditory, and tactile modalities) and motor disconnection was recently reported [11]. Sensory–motor disconnection with preserved awareness can also be observed in extreme cases within the spectrum of acute inflammatory polyneuropathy, such as fulminant Guillain–Barré syndrome (GBS) [12]. In some GBS patients, a complete paralysis extending to cranial nerves can be accompanied by a severe (albeit not complete) blockage of multiple sensory nerves [13–15]. In the initial stages of the condition patients are clearly conscious and can communicate through residual movements. Many report vivid dreams and intense hallucinations, some of which resemble the hallucinations that are induced by weightlessness in astronauts or experienced by those in sensory deprivation tanks [16]. However, all movements are quickly lost and communication becomes impossible. Unresponsiveness can be so deep, even extending to absence of cranial reflexes, that the condition can mimic brain death. However, magnetic resonance imaging (MRI) shows no alteration in the central nervous system and the limited electroencephalography (EEG) available in this condition shows either normal wakeful patterns or mild slowing [13]. In some cases, patient awareness can also be demonstrated by preserved EEG and metabolic responses to auditory stimulation [17] and verbal commands [18]. As the condition persists, the sleep–wake cycle breaks down and the EEG becomes more difficult to interpret. Patients who gradually recover motor control and functional communication tend to be confused and amnestic but some recall having been vividly conscious, albeit in an altered state, while completely paralysed in their acute illness [19,20].

Islands of Awareness

Although dreaming, ketamine and GBS can each involve (relatively) complete disconnection from the environment, in each case the brain retains some capacity for being reintegrated into its environment. Indeed, it is this capacity that enables the retrospective reports which – together with neuroimaging data – supports the inference that consciousness has been retained. However, it is interesting to ask

Glossary

Hemispherectomy/otomy: procedure used for the treatment of certain severe cases of epilepsy in which an entire brain hemisphere is either surgically removed from the cranium and discarded (hemispherectomy), or the connections between the hemisphere and the rest of the brain are cut but the hemisphere itself is left *in situ* (hemispherotomy).
Islands of awareness: conscious stream (or system) whose contents are not shaped by sensory input from either the external world or the body and which cannot be expressed via motor output.
Cerebral organoids: stem-cell-derived laboratory-grown structures that self-organise into three dimensions with cellular and network features resembling certain aspects of the developing human brain.
Perturbational complexity index (PCI): technique in which TMS is used to perturb the cortex, and EEG is then used to measure the electrocortical responses to that perturbation. The algorithmic complexity (information) inherent in that electrocortical response is taken to be an indicator of consciousness.

whether consciousness might also occur even in systems that lack any sensory or motor connections to the body or environment. We call such centres of consciousness 'islands of awareness'. An island of awareness can be thought of as a limiting case of the kinds of sensory and motor disconnections that we have considered above (Figure 1). In each of those cases disconnection is merely partial, for at least some sensorimotor pathways between the brain and its environment are retained. A genuine island of awareness, however, has no sensorimotor interaction with the body that supports it, nor with the environment that surrounds it. It is also important to distinguish islands of awareness from instances of covert consciousness, in which consciousness is not manifested in outward behaviour, and for which there is now significant evidence in at least some behaviourally unresponsive patients who have emerged from coma [21,22]. Islands of awareness are more profoundly isolated: their experiences are causally isolated from both the body and the environment, and in both motor and sensory respects.

In what kinds of situations might islands of awareness occur? It is certainly possible that they might occur in the context of severe multifocal brain injury (Box 1). However, we will focus here on conditions that have not previously been considered in connection with islands of awareness – conditions that have been made possible by advances in neurosurgery and neuroengineering.

We begin with a study by Vrselja and colleagues [23], in which intact pig brains were extracted up to 4 h postmortem and then connected to a system called BrainEx, which delivered nutrients and oxygen to brain cells. Vrselja and colleagues were able to restore and maintain microcirculation as well as molecular and cellular functions of neurons under *ex vivo* conditions for several hours, and without any sensory input or motor output. Significantly, they observed spontaneous synaptic activity in these *ex cranio* brains. Although there was no evidence of global brain activity and no EEG response, that fact might be explained by their use of a preservative solution that inhibited neural activity. Previous research in which guinea pig brains were isolated and perfused *in vitro* in hypothermic conditions but without pharmacological blocking agents has demonstrated preservation of electrical responses across multisynaptic circuits [24] as well as synaptic plasticity [25].

While these data do not provide direct evidence for awareness in a 'naked brain', [24], they certainly raise that possibility. Suppose that the experiment conducted by Vrselja and colleagues were to be repeated without an explicit neural inhibitor and under normothermic conditions. If organised patterns of spontaneous neural activity were to be observed in this situation, the question of whether an island of awareness was present would immediately arise (just as it immediately arises in the case of fully disconnected brains in some GBS patients).

Might islands of awareness occur even in an isolated cortical hemisphere? The relatively rare neurosurgical procedure of **hemispherotomy**, our second case, involves the disconnection of a damaged hemisphere in order to treat children with severe cases of refractory epilepsy [26]. Hemispherotomy aims at maximal disconnection of white matter pathways linking the pathological hemisphere to the brainstem, thalamus, and contralateral hemisphere. The damaged hemisphere is, however, left inside the cranial cavity with vascular connectivity intact. In the related procedure of hemispherectomy, the damaged hemisphere is first disconnected and then removed from the brain entirely. Typical peri-insular hemispherotomy involves severing the corona radiata, resection of the temporal lobe, complete section of the corpus callosum, subfrontal and temporal stem disconnection, and undercutting or resection of the insular cortex [27]. While neural disconnection is usually assumed to be complete, some residual commissural and central connections via the hypothalamus and optic chiasm may remain (Michael Carter, personal communication). It is clear that the intact and properly connected hemisphere supports awareness (for patients are clearly conscious), but could the disconnected hemisphere also support awareness? If so, then there would be an island of awareness in the disconnected hemisphere.

Little is known about the consequence of this radical deafferentation on neural activity in the disconnected hemisphere. One recent study performed intraoperative electrocorticography and found reduced broadband spectral power in regions of disconnected cortex surrounding the pathological

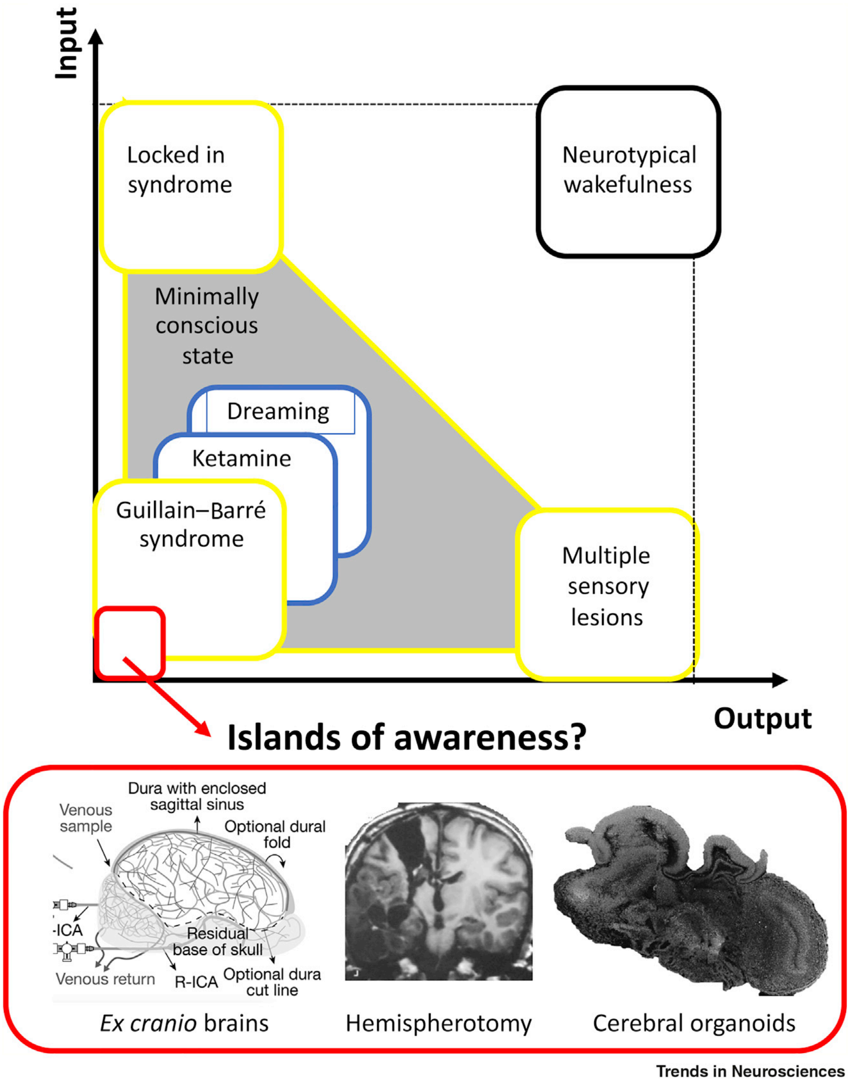

Figure 1. Schematic Representation of Some Possible Instances of Islands of Awareness in Relation to Other Conditions of Consciousness.

The graph represents different conditions as a function of their approximate level of sensory and motor connectedness. The black boundary defines the high level of connectedness typical of healthy awake humans. The blue boundaries include conscious states characterised by forms of disconnection that are functional and reversible (e.g., dreaming, and hallucinations during ketamine anaesthesia). The yellow boundaries include pathological conditions in which consciousness might be preserved in spite of various degrees of structural disconnection. They encompass cases of pure motor disconnection (e.g., locked in syndrome); cases of pure sensory disconnection (e.g., multiple concurrent lesions of sensory systems); cases in which multifocal brain injury may affect both motor and sensory systems to a variable extent (e.g., the large grey area of the minimally conscious state, MCS); and situations that approximate complete, albeit reversible, sensory and motor disconnection (e.g., Guillain –Barré syndrome). The red boundaries identify conditions of complete, irreversible structural disconnection. As depicted in the inset below, they include *ex cranio* brains, disconnected hemispheres post-hemispherotomy and cerebral organoids. *Ex cranio* brains [23], hemispherotomy [26], cerebral organoids [31]; reproduced with permission. Abbreviation: R-ICA, right internal carotid artery.

Box 1. Islands of Awareness in Disorders of Consciousness

Following their emergence from the comatose state, many patients who have suffered from serious brain injury spend a period of time in the vegetative state (also known as the unresponsiveness wakefulness syndrome), in which they fail to produce any behavioural signs of consciousness. However, neuroimaging and EEG active paradigms suggest that roughly 15% of these patients can modulate their brain activity to verbal command, which is indicative of (covert) consciousness [54].

It is possible, however, that these figures misrepresent the true prevalence of covert consciousness in behaviourally nonresponsive patients, for the multifocal nature of traumatic brain injury often results not only in motor and sensory impairments, but also in cognitive and attentional impairments. A significant proportion of these patients might fail both overt and covert tests of consciousness not because they are unconscious, but simply because they are unable to process or cognitively engage with sensory stimuli [11,55]. Such cases highlight the fact that intensive care medicine is likely already creating instances of disconnected consciousness, with the precise nature of the disconnection in any one case due to both structural and functional factors. It is also possible that the behavioural fragments that are sometimes seen in these conditions – such as the utterance of a single word [56–58] – are manifestations of transient conscious experiences, rather than merely being the products of unconscious motor routines. Addressing the challenges posed by genuine islands of awareness, in which the presence of consciousness must be inferred without reliance on any intact sensory or motor pathway, might therefore facilitate the development of increasingly sensitive methods for detecting covert consciousness in post-comatose patients.

tissue [28]. This study also found increased local functional connectivity in this apparently preserved cortex, using mutual information analysis approaches. Intriguingly, an earlier functional MRI (fMRI) study reported surprising and unexplained task-related blood oxygenation level dependent (BOLD) activations in a disconnected left hemisphere, following left hemispherotomy in a child with Rasmussen's syndrome [29].

Additional evidence about electrophysiological activity in isolated cortex has been provided by recordings in cortical volumes of various sizes (cortical slabs), which are deafferented from the rest of the brain through a white matter undercut. Timofeev and colleagues [30] showed that small isolated cortical volumes (10 × 6 mm) can sustain sporadic depolarizing events at a frequency of 0.03–0.1 Hz. Notably, the pattern evolves toward a sleep-like slow oscillation in the delta range (~1 Hz) if the volume of the cortical slab is larger (30 × 20 mm, roughly corresponding to a cortical gyrus), allowing for more recurrent excitatory activity.

This stereotypical pattern resembles the slow oscillations normally observed in intact brains during dreamless sleep and may result from a lack of input from the thalamus and subcortical activating systems to the isolated cortex. This raises the possibility that replacing that input – for example, by direct electrochemical stimulation of cortical neurons or long-term homeostatic processes – might restore adequate levels of cortical excitability, and with this perhaps also some form of consciousness (Box 2).

The third case in which islands of awareness might occur involves cerebral organoids. These are laboratory-made 3D structures derived from stem cells that display various features of the developing human brain [31]. Cerebral organoids are sometimes called 'mini brains', although it is arguable that this overstates their similarity to normal brains. The primary use of cerebral organoids has been as laboratory models of neurodevelopmental disorders such as Zika-virus-induced microcephaly, but prospective applications could encompass a wide range of neurological conditions [32]. Progress in cerebral organoid development has been rapid, with recent organoids demonstrating mature neurons and established network structures. Assessment of neural activity using calcium imaging and high-density silicon microelectrodes has revealed spiking activity [33] and complex oscillatory waves resembling some features of human pre-term EEG [34]. While cerebral organoids still lack a well-defined neuroanatomical axis, as well as vascular and nutrient-delivery systems, it is not unreasonable to suppose that near- or mid-term developments will deliver organoids displaying substantial structural and functional similarities to developing human brains.

Box 2. What Is an Enabling Factor?

An important issue raised by many disconnection scenarios concerns the role that subcortical systems places in the generation of consciousness. These systems are often described as enabling factors for consciousness, but that phrase can be understood in two ways: causally or constitutively. In the causal sense, an enabling factor makes a causal contribution to the target process in the way in which a lightning strike might cause a forest fire, such that its causal contribution could in principle be provided by another process (say, a burning cigarette). If subcortical systems are enabling factors in this sense then it is at least possible that their causal role could be replaced by some other factor (say, electrochemical stimulation), and cortical processes alone might suffice for consciousness. In the constitutive sense, an enabling factor is a crucial component of the minimal neural substrate of consciousness. Its role is not to cause cortical systems to enter a state in which they generate consciousness – rather, subcortical activation is itself a component of the neural basis of consciousness. On one version of this account, subcortical activity does not explain why consciousness has the particular contents that it does (it is not part of the differentiating neural correlates of consciousness), but it does play an essential role in explaining why consciousness of any kind occurs (it is a nondifferentiating correlate of consciousness). If subcortical systems turn out to be enabling factors in the constitutive sense, then islands of awareness would not be possible in a disconnected cortical hemisphere, but would still occur in the context of an *ex cranio* brain in which cortical activity was appropriately integrated with subcortical activity. Alternatively, different subcortical structures might turn out to be enabling factors of different kinds. For example, brainstem activating systems and midline thalamic nuclei, modulating the excitability of cortical neurons, might have a casual role, whereas high-order thalamic nuclei and (say) the claustrum, granting tight structural integration among distant cortical areas, might be constitutive.

Assessing the possibility of consciousness in cerebral organoids faces challenges that do not apply to the other cases we have discussed. On the one hand, organoids develop as intact wholes, without having ever had any causal interaction with the external world. This might be thought to mitigate against consciousness if such connectivity is constitutively necessary for developing consciousness (Box 3). At the same time, the fact that organoids develop 'naturally' and do not suffer from radical disruption to their neural structure (in the way that *ex cranio* brains and hemispherotomy patients do) might be thought to argue in favour of the possibility of conscious organoids. In short, the question of consciousness in cerebral organoids remains open. Figure 1 summarises the various cases that we have examined thus far, including both cases of disconnected consciousness (in which connection can sometimes be regained) and what we term islands of awareness, in which neither sensory input nor motor output can be achieved.

Detecting Islands of Awareness

Our capacity to tell whether another creature is conscious ordinarily relies on inferences from behaviour, and by definition islands of awareness have no motor output. Although methods have been developed for detecting consciousness in behaviourally nonresponsive patients [21,35,36], most of these methods require intact sensory pathways and thus they cannot be applied to the cases that we are considering here. How then might genuine islands of awareness be detected?

One interesting possibility is that consciousness can be detected by assessing causal interactions within the brain, even when reciprocal interactions with its surrounding environment are completely interrupted. A practical way of probing the internal causal structure of the brain involves a perturb-and-measure approach through a combination of cortical stimulation and neuroimaging [37]. An example of this method is provided by the **perturbational complexity index (PCI)** in which the cerebral cortex is first stimulated by transcranial magnetic stimulation (TMS) and then EEG is used to measure the complexity of the cause–effect chain of neural activations triggered within the brain [38]. PCI has proven effective in detecting disconnected awareness during dreaming and ketamine anaesthesia [39] and proven able to identify conscious patients who are minimally responsive, or fully unresponsive, following severe brain injury [40]. In spite of its high accuracy, the general applicability

Box 3. Validating Measures of Consciousness

Validating novel measures of consciousness that can be used to detect consciousness in difficult cases – such as those involving putative islands of awareness – raises deep methodological challenges [59–61]. The standard approach to validating a novel measure is to correlate the presence/absence of that measure with a given pretheoretical measure of consciousness, such as behavioural responsiveness. However, this approach faces problems when making inferences in cases where the pretheoretical measure by definition cannot be obtained, such as in disconnected patients. To address this problem, a measure's validation can be extended to fit also cases of disconnection; for example, by relying on delayed report upon awakening from dreaming and ketamine dissociation. This validation strategy has already been utilised to allow for improved inference in brain-injured patients with sensory and motor disconnection [39]. More generally, confidence in novel measures can be gained on the basis of their overall convergence with multiple pretheoretical and previously validated measures of consciousness [62–64]. Confidence is further increased when such measures can be demonstrated to operationalise a particular theory of consciousness, to the extent that that theory shows general explanatory and predictive power.

A second challenge is that measures of consciousness validated or otherwise applied in adult human beings might not transfer to (say) infants or nonhuman animals. This worry applies with particular force to cerebral organoids, because the kinds of neural activity that support consciousness in an organoid might differ in important respects from those that support consciousness in human brains. Relying on similarities between organoid activity and human brain activity might lead both to the overattribution of conscious states to organoids (false positives; [33]) and, simultaneously, to the underattribution of conscious states (false negatives) given that organoid consciousness might involve very different kinds of activity patterns. Having said this, if theoretically grounded and empirically robust measures applicable in humans are applied with similar results in nonhuman cases, this should be taken as highly suggestive of consciousness in such cases.

The history of science has repeatedly encountered the problem of validating measures of incompletely understood phenomena, when accurate measurement is in turn essential for reaching a satisfying scientific understanding of the target phenomenon. For example, the development of reliable thermometers faced and overcame these problems in catalysing a physical explanation of heat [65]. Similarly, careful and incremental extension of novel measures of consciousness to difficult cases could similarly catalyse a deeper physical understanding of the nature of consciousness that could then in turn further validate these novel measures.

of PCI presents practical challenges, including (for hemispherotomy) the risks posed by electrical stimulation of an epilepsy-prone brain.

There are, however, ways to estimate the complexity of neural dynamics without applying cortical perturbations. For example, measures of the algorithmic complexity of spontaneous EEG can track loss of consciousness across sleep and anaesthesia in humans [41–43]. Indeed, multivariate pattern analysis has shown that among all EEG features those that contribute most to the correct discrimination between conscious and unconscious patients are long-range connectivity and time-series complexity [44]. Further evidence that the dynamic complexity of intrinsic brain networks represents a reliable marker of consciousness has been provided by Demertzi and colleagues [45].

Given the sensitivity of network complexity measures in detecting a capacity for consciousness in challenging cases such as ketamine dreams and minimally conscious [39] and massively disconnected patients [11], they might be usefully applied to the even more challenging cases involving total disconnection. In principle, one could ask whether isolating, disconnecting, or growing brain islands allows for complexity levels comparable with the ones found in dreaming subjects, or in the injured brains of minimally conscious patients. Clearly, the thresholds and classifiers that currently allow accurate detection of consciousness in healthy subjects and neurological patients may become less reliable as we move toward atypical neural structures (Box 3). Nonetheless, these techniques would enable us to ask fundamental questions. Is it possible for *ex cranio* brains to display levels of complexity that are comparable with those displayed by the *in cranio* brains of conscious subjects? If so, for how long might that complexity be sustained? Could the disconnected hemisphere of a hemispherotomy patient host network dynamics that are as complex as the ones seen in the contralateral hemisphere, or does it plunge irreversibly into a deep sleep state due to lack of ascending

Box 4. Theories of Consciousness

One contrast between different theories of consciousness concerns the predictions that they make about when islands of awareness will (and will not) occur. Indeed, there is a more fundamental distinction between those theories of consciousness that allow for the possibility of islands of awareness and those that do not.

Those who are sympathetic to externalist accounts of consciousness are unlikely to hold that islands of awareness are possible, for externalists argue that the constitutive physical basis of consciousness extends beyond the brain and loops out into the body and environment [66,67]. If the existence of islands of awareness can be established, then that would place pressure on externalism.

Most theories of consciousness presuppose some version of internalism, and hold that the constitutive basis of consciousness is exclusively brain-bound. On this view, the body and the wider environment are only causally relevant to consciousness (see Box 2 for more on causality in this context). All internalist accounts hold that islands of awareness are possible, but different internalist theories make different predictions about the conditions under which islands of awareness might arise. For example, higher-order theories of consciousness predict that islands of awareness will arise when and only when a system for generating the appropriate kinds of higher-order representations is active [68]; global neuronal workspace accounts predict that islands of awareness require nonlinear global ignitions of activity involving (functional equivalents of) both parietal and frontal circuits [69]; and the Integrated Information theory predicts that brain islands will be conscious in a graded fashion depending on their intrinsic cause–effect power as measured by Φ [70]. In principle, then, the investigation of islands of awareness provides an important and informative constraint on theories of consciousness.

neuromodulation (Box 2)? Are there conditions in which cerebral organoids develop patterns of internal interactions that become progressively richer, or do such rich dynamics require a history of interaction with the environment? Addressing these questions would tell us much about the neural basis of consciousness.

Methods like PCI and other complexity measures may be able to detect an unsuspected capacity for consciousness in disconnected brains, but they cannot shed any light on the potential conscious contents that might occur in these islands. One in-principle approach would be to use stimulus-free neural decoding methods, such as those developed by [46] to decode the contents of dream experiences. Clearly, however, decoding conscious contents from within putative islands of awareness will be challenging. Although there is some evidence of robust mappings from neural activity to perceptual content in neurotypical subjects [47], it is doubtful that these mappings will also apply to atypical brains. Thus, the question of what kinds of contents might occur in islands of awareness is likely to present some of the deepest challenges hereabouts. We might be able to tell that there is something it is like to be a disconnected brain without being able to tell just what it is like.

Concluding Remarks

Suppose that we were to discover evidence of islands of awareness in *ex cranio* brains, hemispherotomy patients or cerebral organoids: what implications might such findings have (see Outstanding Questions)?

Let us begin with implications for accounts of consciousness (Box 4). The discovery of consciousness in a reanimated brain would indicate that ongoing dynamic interaction with the external world is not a necessary condition for consciousness. Although this finding would be in line with some accounts of consciousness, other accounts hold that neural systems are conscious only insofar as they are in ongoing dynamic interaction with their environment. Of course, even if a reanimated brain were able to sustain an island of awareness for a short period of time, it is entirely possible that external input (entrainment) would be needed for consciousness to be sustained in the longer term. The theoretical questions raised by cerebral organoids also concern the role that the environment plays in consciousness, although now the question is not only whether consciousness requires ongoing dynamic interaction with the environment, but whether it also requires a history of such interaction. Among the theoretical questions raised by hemispherotomy is whether consciousness requires subcortical input, or whether cortical activity alone might be sufficient to sustain consciousness. In short, the discovery of islands of awareness in any one of these three cases would reveal something important about the nature of consciousness, although different things would be revealed in each case.

A different set of implications that the discovery of islands of awareness would have is ethical and legal. The reanimation of *ex cranio* brains raises questions about personal identity and the nature of death. Suppose that whole brain reanimation were to occur in a human rather than a pig, and that pharmacological agents were not used to preclude organised neural activity. Would complex neural activity in such a brain, indicative of consciousness, ensure the continued existence of a particular individual, or does personal survival require (for example) a sense of bodily identity or agency? These questions are also raised by other conditions (such as dementia and serious brain injury), but they would be prompted in a particularly vivid fashion by the prospect of whole brain reanimation [48]. The discovery of an island of awareness in a hemispherotomy patient would also raise questions of personal identity. Would the experiences associated with the island of awareness belong to a separate subject of experience – a subject whose interests might diverge from those of the communicating subject – or should we think of the patient as a single subject of experience who happens to have two streams of awareness (one of which is isolated and one of which is not) [49,50].

The ethical challenges raised by the prospect of conscious organoids do not turn on questions of personal identity but on questions of moral status and standing [51–53]. How should conscious organoids be treated? What would it be to respect their well-being and interests? Should their treatment be governed by animal welfare laws, or would it require a new legal framework? Would it be permissible to engineer conscious organoids for research purposes, or would that violate their dignity? These questions should occupy a central place in the agenda of consciousness science.

In summary, advances in neurosurgery and neurotechnology may soon generate the capacity to create islands of awareness. It is not impossible that they may already have done so. It is imperative that the scientific and ethical consequences of these developments are subjected to careful consideration, alongside development of methods tuned to the detection of islands of awareness in the various different contexts in which they might arise.

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Outstanding Questions

- Might (reversible) islands of awareness occur in contexts other than the ones that we have considered, such as epileptic absence seizures, or local islands of awareness in an otherwise sleeping brain?
- What other methods might there be for detecting islands of awareness?
- What animal models can be developed for investigating islands of awareness? For example, could animal hemispherotomy preparations be studied, with and without preservation of visual input to the otherwise disconnected hemisphere?
- What methods are there for interacting or communicating with an island of consciousness?
- Are islands of awareness possible for only short intervals, or could the disconnected brain sustain consciousness for prolonged periods of time?
- Are there some kinds of conscious contents that cannot occur in the disconnected brain, or that could only occur in such situations?
- Does the nature and distribution of islands of awareness discriminate between competing theories of consciousness?

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