

ARE CURRENT PHILOSOPHICAL THEORIES OF CONSCIOUSNESS USEFUL TO NEUROSCIENTISTS?

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ABSTRACT: Two radically different families of theory currently compete for acceptance among theorists of human consciousness. The majority of theorists believe that the human brain somehow causes consciousness, but a significant minority holds that *how* the brain would cause this property is not only currently incomprehensible, but unlikely to become comprehensible despite continuing advances in brain science. Some of these latter theorists hold an alternate view that consciousness may well be one of the fundamentals in nature, and that the extremely complex functional systems of the human brain inform this basic property, giving rise to our specifically human variety thereof. If these contesting families of theory are to be useful to neuroscientists, testable notions flowing from these theories need to be developed.

Key words: consciousness, panpsychism, operationalize

Before focusing on the title question, it will be helpful to address three preliminary points. First, we need to define human consciousness. Attempts to provide a formal definition have proven difficult, partly because the term has been used in so many different contexts. For instance, Lycan (1996) has provided eight different ways in which the term has been applied, along with the appropriate caution that “none of us gets to kidnap words like ‘conscious’” (p. 164). Additionally, it may be the case that consciousness is so fundamental as to resist further analysis. That is to say, while consciousness can be categorized in a large variety of ways, for instance in respect to content and vividness, its core feature—often referred to metaphorically as the “light of consciousness”—does not seem to be decomposable into more basic elements. In any case, for purposes of the present paper I will start with a definition provided by Searle (1997), who noted:

It is supposed to be frightfully difficult to define the term [consciousness]. But if we distinguish between analytic definitions, which aim to analyze the underlying essence of a phenomenon, and common sense definitions, which just identify what we are talking about, it does not seem to me at all difficult to give a common sense definition of the term: “consciousness” refers to those states of sentience and awareness that typically begin when we awake from a dreamless sleep and continue until we go to sleep again, or fall into a coma, or die, or

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otherwise become “unconscious.” Dreams are a form of consciousness, though of course quite different from full waking states. (p. 5)

Second point: Many theorists who have labored for a lifetime over the issue of consciousness come from an academic background in philosophy, and it has often been claimed that philosophical theorizing occurs at too abstract a level to be scientifically testable. However, this traditional distinction fails to take into account a fact that Kuhn (1970) so famously noted: “There are seldom many areas in which [even] a scientific theory. . . can be directly compared with nature” (p. 26).

The reason is easy to appreciate: While the label “theory” can be applied to notions at various levels of generality, more encompassing theories involve greater degrees of abstraction. In these important cases, scientists must infer more specific notions that would flow from the theories— notions that are sufficiently detailed to allow for empirical investigation.

To illustrate the point, we might examine an instance taken from a well-known philosophical theory of mind. Immanuel Kant judged that because the Principle of Causality cannot be learned from the experience of our surroundings—we *perceive* only antecedent and consequent—the notion must be built into the human mind. His conclusion, evoked by the reading of David Hume, stood in sharp contrast to John Locke’s notion that the human mind at birth is a blank slate and that everything in the intellect must first have been in the senses.

In order to investigate Kant’s theory scientifically, we would first need to operationalize it, in the sense of deriving consequences that are testable. So, for instance, if his thesis is correct we might expect to find strong evidence of causal awareness even in the youngest of minds, and we would note that this inference tends to differ from what we might expect if Locke’s competing thesis were true. For in that case we might expect learning about causality to occur somewhat later, and perhaps only gradually as children accumulate life experience—including, especially, the verbal experience that is so distinctively bestowed on our species.

Here is a pertinent experiment: Using techniques that have been ingeniously devised for application to preverbal children, Cohen and colleagues (1999) showed that infants tested at about six months of age—barely time for their brains to have developed the connections needed for reliable detection of discrete objects and precise movements—gave similar interpretations to visual representations of causally interacting objects as adults who viewed the same sequences. Since this result is highly congruent with Kant’s thesis, and less so with Locke’s, we have experimental evidence that tends to favor Kant’s theory over that of Locke.

We can also conclude in a more general way that philosophical theories, at least on some occasions, can give rise to experiments that differentially support their validity. It goes without saying that “supporting” a theory is not the same as “proving” it, so a third preliminary point is that theories seldom stand or fall on the basis of one observation or experiment. This is because, in the majority of cases, a theory can be amended to accommodate one or another “anomalous” finding (a point that will be illustrated later).

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Within the above context, we will examine the question “Are current philosophical theories of consciousness useful to neuroscientists?” Specifically, we will focus on the two *radically differing* families of theory that have been mustered in an effort to explain the presence of human consciousness, bearing in mind that to be scientifically helpful the theories in question must be able to generate inferences of a nature that can usefully inform empirical investigation.

Relation of *Animal* Consciousness to Animal Behavior

Placing the issue of human consciousness initially in the more encompassing context of animal consciousness provides a useful perspective because no other animal’s consciousness is immediately observable; hence, it always needs to be inferred from behavior. In former times, when conscious choice constituted the default explanation for complex goal-directed behavior, consciousness was attributed to animals in order to explain their many instances of flexibly adaptive behavior. But a funny thing happened on the way to modern neuroscience. A group of psychologists, the Behaviorists, started asking questions like “Who knows what a rat is thinking?” Since they judged that such questions would always remain unanswerable, they attempted to explain what animals do on the basis of observables like emitted behaviors and external reinforcements (e.g., Skinner, 1938).

Such Behaviorist models, elegant in their simplicity, turned out to be amazingly useful in helping us understand the adaptive behavior of animals with no need to hypothesize what an animal might be thinking—and indeed without even having to consider whether or not an animal was consciously thinking at all. Of course, these simple models suffered from a severe limitation, since the brain was treated as an inscrutable “black box.” This restriction became unnecessary by the latter part of the twentieth century as neuroscientists devised multiple techniques for studying functional responses within the brain itself. But since behavioral choices could now be correlated directly with activation of specific neural systems, there continued to be little need to speculate about the possible content of an animal’s putative consciousness in order to explain its behavior.

As such experimental approaches became commonplace, however, a particular irony started to strike theorists with mounting force. It was an irony that made any reintroduction of animal consciousness about as welcome to many theorists as the return of Jesus had been to the Grand Inquisitor. Conscious choice, the former default explanation for complex goal-directed behavior, was not only *no longer needed* in order to provide an explanation for animal behavior, but any attempt at reintroduction of this putative property led to a horrendous theoretical difficulty known as the “causal closure” problem. That is to say, if an animal’s nervous system is operating normally in terms of (A) its detection systems, (B) its information processing systems (with all their crucial *weighting* attributes), and (C) its intimately connected effector-systems, then the appropriate behaviors will occur. If these systems are seriously impaired, then the goal-directed behaviors

associated with their functioning will break down. Consciousness had nothing left to do but needlessly reiterate what had already been causally explained.

In summary, animal consciousness is not something we can observe. To posit this property requires inference from an animal's behavior (inference, it might be added, that tends to be heavily gilded with anthropomorphic projection). So when animal behavior became explainable, in principle, as the result of the activity of neural systems, consciousness as an *inferential construct* to explain the occurrence of complex, goal-directed behavior was no longer needed. Worse than that, if theorists tried to reintroduce this notion as an addition to their neural systems explanation for animal behavior they created for themselves the problem of causal duplication.

It should perhaps be added that this problem accounts, in part, for the espousal of a highly counterintuitive thesis such as epiphenomenalism by many theorists. James (1890) provided a neat illustration of the relevant type of phenomenon: "the shadow runs alongside the pedestrian, but in no way influences his steps" (p. 133). In the present context, if consciousness does no work, then the causal closure problem disappears.

Relation of *Human* Consciousness to Human Behavior

Within the context of natural selection, *Homo sapiens* is simply one more animal species on planet Earth. In certain respects, therefore, the above considerations apply. Hence, if highly intelligent extraterrestrials landed on Earth, they would presumably be able to address the behavior of our species (including our species-specific verbal behavior) in the same fashion that we now use when addressing the behavior of our fellow planetarians. In fact, some human theorists of mind, the Eliminativists, do just that, and their stance—incredible as it may seem to the average person—does indeed offer at least three advantages in the realm of theory. Their approach is more parsimonious, it avoids the causal closure problem, and it avoids the seemingly intractable problem of providing a naturalist explanation of consciousness.

Unfortunately, however, most members of *Homo sapiens*—including even those accustomed to the thin air atop our ivory towers—have been unable to "feign anesthesia" with sufficient consistency to adopt this thesis. Alternately stated, we *know* that our species is conscious because we are directly acquainted with this property each and every day. It not only is a fact; it is THE central and decisive fact of our human lives, so much so that few of us would choose to be kept alive if it meant spending the rest of our days in a purely vegetative state.

However, we immediately need to provide an important qualification regarding the above statement that "*we* are directly acquainted with this property." It would be more accurate to say that "*each one of us* is directly acquainted with this property," given the fact that each one is *not* directly acquainted with the consciousness of anyone else. Nor can we perceive the presence of this property in our fellow humans by means of our senses. Consciousness is experienced only from the "inside," so each person experiences only his or her own consciousness.

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Hence, each of us must establish the presence of consciousness in others of our kind by noting their goal-directed behavior along with reports of what they are experiencing. It is in fact chastening for physicians to note the limited evidence actually available to them as they go about trying to observationally determine the presence of consciousness in doubtful cases (cf Sullivan, 1996).

We need yet another qualification, for although theorists can (and do) make explicit inferences concerning the presence of consciousness in their fellow humans, no such process intervenes in the “automatic inference” of most people, most of the time. Strawson (1985) stated the case:

The best argument against other-minds skepticism is, probably, that, given the non-uniqueness of one’s physical constitution and the general uniformity of nature in the biological sphere as in others, it is in the highest degree improbable that one is unique among members of one’s species in being the enjoyer of subjective states. . . (p. 20)

He then went on to emphasize: “This is no one’s reason for believing in the existence of other minds. . . .We simply react to others as to other *people*” (p. 21, author’s emphasis). From early childhood, that is, children believe unquestioningly that the other humans around them are conscious, because we are programmed to take this for granted.

Given the fact that we cannot directly perceive consciousness in others, whenever scientists perform experiments pertaining to human consciousness they rely on a subject’s associated behaviors. Since verbal behavior is the most highly specified in this regard, verbal reports of a subject’s conscious experience are generally the most useful. For instance, we know that visual areas in the occipital cortex become more active, as measured by various neuroimaging techniques, whenever a person looks at a scene. What happens, however, when a person does not look at a scene, but instead imagines it at the experimenter’s request? Subjects routinely *report* success in performing such conscious acts—and as might be anticipated, areas of occipital cortex devoted to vision become more active as they are doing so.

The verbal link between behavior and consciousness is so crucial in life (and not just to neuroscientists in their correlation experiments) that some theorists have actually defined consciousness as “reportability,” an excess of enthusiasm on their part for the wonders of our human communicational abilities. But if we were to express the actual relationship between consciousness and reportability in philosophical parlance, we might say that reportability involves the way we learn about the content of another’s consciousness—an epistemological issue—whereas the occurrence of conscious states involves an ontological issue.

What Causes Human Consciousness?

Demonstrating a correlation between certain brain activities and specific kinds of conscious experience does not, of itself, provide a causal explanation for this unique property. In fact, there is a bidirectional problem: What mechanism is to

give rise to conscious thoughts in the first place? Secondly, once conscious thoughts do occur, how are they, in their turn, to causally influence neuronal membranes? I refer to this nitty-gritty level of interaction in order to make more concrete the sort of physical process that this putative causal agent, “a conscious thought,” would have to be able to set in motion.

Scientifically Rejecting a Theory of Consciousness

Current theorists most often start their exercise with the Cartesian theory of consciousness, and it will be useful for us to do that since Descartes’ substance-dualism illustrates how an abstract theory of consciousness can generate more specific notions that are testable in scientific fashion (i.e., by careful observation and/or experiment). Descartes postulated the existence of a separate immaterial substance that was to be responsible for the property of human consciousness. The putative existence of such a “thinking thing” (*res cogitans*) to underwrite consciousness gives rise, in turn, to the following *testable* thesis: Since the material body, specifically the human brain, is not the cause of our consciousness—which is due to the operation of this immaterial thinking substance—consciousness will continue whether or not the human brain is functioning normally.

Descartes’ thesis failed to pass muster in this regard because it was inconsistent with the pertinent findings, which are these: If there is a normally functioning human brain, then normal human consciousness will occur; if injury is sustained by brain areas associated with cognitive function, then impairment of human consciousness will occur; if severe injury is sustained in the relevant brain areas, then *no* human consciousness will occur. This leads to a mismatch between Cartesian theory and scientific fact, for if a totally separate “thinking thing” had been responsible for our human consciousness, then severe disruption of brain function would not have interfered with the thinking thing’s core activity—namely, to be conscious.

As is the case with most theories, substance dualism can be adjusted into some sort of compatibility with the facts. For instance, one might say that the thinking thing’s activity is necessary but not sufficient for consciousness—but such an alteration would require us to postulate an entity, the “thinking thing,” that does no actual work (except for the task of maintaining a semblance of harmony with Platonic theory and hoary folk stories of body and soul). Hence, modern theorists of consciousness have, by strong consensus, rejected the thesis of substance dualism as simply otiose—though it should be noted that dissenters from this consensus have lingered through the twentieth century, including, most notably, the Roman Catholic neuroscientist Sir John Eccles (1980/1992), along with J. Foster (1991) and R. Swinburne (1986).

What if the findings had, in fact, turned out differently? What if human consciousness had continued during periods when the brain lapses into one of the severely dysfunctional states that we associate with coma? What if, for example, acute trauma patients, with brain functioning so disordered that their EEGs were

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for a time totally flat, reported consistently on recovery that they had been continuously conscious throughout their entire ordeal? In that case, strong empirical evidence would have been available that consciousness occurs in the absence of a functioning brain, a finding that, in turn, would have been quite congruent with a separate and separable “thinking thing.”

In that case neuroscientists would not have been able to reject the thesis of a separable “thinking thing” on the basis of the actual findings. The possibility of interaction between a “thinking thing” and brain would then have had to have been acknowledged—though *how* this would have worked might seem as enigmatic as, say, the particle/wave phenomenon that continues to boggle the minds of current particle physicists. But the actual fact turned out to be that consciousness is always associated with a functioning brain—not necessarily a *normally* functioning brain, since illusions of separability can be experienced during phenomena like the so-called “out of body” experience. During such states, however, the brain is still functioning, albeit in an altered state (cf. Sullivan, 2005, Ch 23).

Theories Compatible with Neuroscience

Because it has become accepted fact that human consciousness occurs only with a functioning brain, and because normal consciousness requires a normally functioning brain, all scientifically viable theories have come to look at our consciousness as a function of human brain activity. Alternately stated, virtually all current theories of human consciousness are *monist*.

The Human Brain as the Cause of Human Consciousness

Here is the explanation (henceforth referred to as “Thesis A”) most often provided by current theorists: The functioning human brain *causes* consciousness. Unfortunately for this straightforward notion, however, closer examination reveals serious problems.

First, unlike ordinary instances of causation occurring at higher levels of complexity, *how* consciousness is to be caused by brain function remains totally mysterious. To illustrate: Some theorists have compared consciousness with other biological functions such as digestion. Just as a functioning gastrointestinal tract will bring about digestion, a functioning brain will bring about consciousness. As Searle (1992) stated the case: “Consciousness is, thus, a biological feature of certain organisms in exactly the same sense of ‘biological’ in which photosynthesis, mitosis, digestion, and reproduction are biological features of organisms” (p. 93).

In all these other instances, however, we know in some detail *how* the effects come about. For example, when we examine the various processes occurring in the gastrointestinal tract we can understand clearly how digestion occurs. Regarding nervous system function, we also can understand clearly how things such as sensory detection and information processing occur. In sharpest contrast, we have not the foggiest notion of how brain function might cause consciousness.

In response to this problem, those who favor the above approach (i.e., the majority of current theorists) usually counsel patience, noting that neuroscience is still a very young field. The chief limitation of this stance is that relevant neuroscientific studies simply start with the occurrence of human consciousness as a given to be reported and deal only with the occurrent *correlations* between brain functioning and conscious reports. There has been no movement whatsoever when it comes to the task of understanding *how* the brain might actually cause consciousness.

In the other direction—how a conscious thought is, in its turn, to causally influence neuronal membranes—those who accept the reality of conscious thoughts seem to face an intractable problem unless they espouse some form of dual aspect theory. Thus, although the neuroscientist Joseph LeDoux (2002) does not refer to his explanation by this label, his statements clearly imply this sort of construct. For instance, he says:

Downward causation is only mind-boggling if you believe that thoughts are one phenomenon and brain activities another. . . .If a thought is embodied as a pattern of synaptic transmission within a network of brain cells, as must be the case, then it stands to reason that the brain activity that is a thought can influence activity in other brain systems. . .” (p. 319)

LeDoux’s thesis falls short of being a full-blown causal explanation, however, because it provides no explicit account of how “a pattern of synaptic transmission” is to be equated with a conscious thought.¹

Consciousness as a Fundamental Property in Nature

Faced with the continuing enigma of how the human brain is to cause consciousness, some naturalists (cf McGinn, 1993) have considered it likely that our human information processing skills remain as “cognitively closed” to grasping the relevant causal connections as a rat’s neural apparatus remains closed to the comprehension of differential equations.

Others, like Thomas Nagel, have wondered whether consciousness, at least in some sort of proto form, might not constitute a fundamental aspect of all nature. As Nagel (1986) stated the proposition:

The falsity of physicalism does not require nonphysical substances. It requires only that things be true of conscious beings that cannot, because of their subjective character, be reduced to physical terms. Why should the possession of physical properties by the body not be compatible with its possession of mental properties—through some very close interdependence of the two. Perhaps, as Spinoza believed, the properties are ultimately the same, but that would have to be at a level deeper than either the mental or the physical. (p. 30)

¹ By contrast, Spinoza’s explicitly developed dual aspect theory, which postulates consciousness as a fundamental in nature, *is* able to underwrite a causal account of its occurrence in *Homo sapiens*.

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More recently, in response to the same causal enigma, David Chalmers (1996) has speculated about basic protophenomenal properties that would become informed by our complex functionalist systems, giving rise to what we experience as our human consciousness. Since this family of explanations (henceforth referred to as “Thesis B”) represents a minority view, I will outline the merits of such dual aspect views in a bit more detail.

This family of theories has two highly attractive features. First of all, the *modus operandi* being used mirrors that of our much admired particle physicists in a crucial respect. In the case of these scientists, if a given particle or force cannot be reduced to anything *more* fundamental, then it is to be taken as one of the basic ingredients of the universe (hence the 4-force-12-particles of our current Standard Model). In similar fashion, then, a dual aspect theorist would expound the thesis that consciousness should be treated as another of the fundamentals in our universe since it is not *comprehensibly* derivable from a 4-force-12-particle causal base after allowing for as many levels of complexity as a theorist might wish to employ.

Additionally, dual aspect theories circumvent the enigma that results from the causal closure problem since human consciousness is envisioned as a view from the inside of *one and the same causal flow* that we can also view from the outside. To illustrate: A person may consciously decide to press a lever now—the view from inside—or the same activity may be viewed from the outside by demonstrating the associated pattern of complex neural activity. For the dual aspect theorist these are not two separate things that must causally interact; they are simply two different aspects of one and the same causal flow.

Despite such attractive features, however, the majority of current theorists have rejected a dual aspect thesis in nature. One of their key concerns has to do with the judgment that this thesis amounts to animism, for if some basic form of consciousness is to be posited as one of the fundamentals in nature, would this not imply that all the items we come across, from dolls to doorknobs, are conscious? To wit, would we not be retrogressing to days of yore when animism was an all too familiar aspect of our human explanatory stories?

In responding to this concern, it is crucial to start with our earlier point that the only direct access we have to consciousness is *from the inside*—that is, from the experience each of us has of our own personal consciousness. We feel most confident when extrapolating from our own kind of experience to other members of *Homo sapiens*, and progressively less confident when extending our empathic sense to members of other species, even those relatively close to our own. When attempting to do so, naïve members of *Homo sapiens* have a pronounced tendency to simply project our own type of consciousness onto members of these other species. The more sophisticated among us try at this point to subtract those features of our consciousness that other organisms obviously lack. For instance, even fellow primates like chimpanzees have, at the very most, primitive language skills, so we try to *imagine* a consciousness without language (a rather difficult task to carry through).

If the attempt to envision the nature of consciousness in individuals as close to us as our fellow primates is fraught with problems, the difficulty only increases as

we go down the scale of complexity in animal life. What we observe, in effect, is a gradual peeling off of belief in consciousness as we traverse the phylogenetic scale of complexity. Indeed, some notable theorists of mind such as Carruthers (1998) draw a line immediately below our own grand and glorious species—at least, that is, when operating in theoretical mode.

The bottom line: It is difficult for us *not* to conflate a more general notion of consciousness with human consciousness, and if we have difficulty in imagining the presence of consciousness in even the higher animals without resorting to anthropomorphic projection, it is totally impossible for us to imagine the putative consciousness of, say, a humble ant (never mind the extremely primitive consciousness that might be proposed for elementary functional systems like thermostats).

In order to avoid being animistic it becomes necessary for us to avoid even *trying to imagine* what a property of basic consciousness might be like. Instead, we need to grasp the concept in abstract fashion—and perhaps it should be stressed at this point that such an approach is not antiscientific. For example, human imagination is limited to picturing three dimensions, so none of us can actually visualize Einstein's four dimensions, let alone the ten or more dimensions of string theorists. Hence, all such notions need to be managed in abstract mode.

How Would Neuroscience Decide Between Theses A and B?

For neuroscientists, two significant questions arise at this point: First, do current scientific findings favor either thesis A or thesis B? Perhaps more importantly, can these theses be operationalized in ways that might lead to (dis)confirmatory observations and experiments? If not, the theories involved would be of no specific use to neuroscientists.

Although one might have a strong tendency to believe that such *radically different* theses would be easy to distinguish in nature, the task of deriving testable consequences is actually quite difficult. One reason is that both thesis A and thesis B were hammered out in the first place so that they would be congruent with the core finding of relevance to human consciousness, namely that this property arises only in conjunction with a functioning human brain. Hence, theory construction in either case has kept a vigilant eye focused on this one key correlation.

Within that context, each theory has had to address the following question: If the functioning of our human brain is to explain human consciousness, how are we to account for the marked dissociation found between consciousness and most of our ongoing brain activities (everything from the complex and widespread systems necessary for the control of blood pressure and body temperature to the many timely movements performed automatically when, say, driving an automobile)?

Causal theories of consciousness provide the following response: Only certain clusters of brain activity cause our consciousness. Not surprisingly, explanations provided by dual aspect theorists follow a parallel path. In order for the experience of *human* consciousness to occur, such theorists would claim, the same sorts of brain mechanisms must be operative.

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What sorts of mechanisms? Here are some of the more specific brain activities that theorists have focused on: frontal lobe attentional and working-memory systems (e.g., LeDoux, 2002); widespread dissemination of information across the brain (e.g., Baars, 1988); information processing systems that monitor the processing of subsystems (e.g., Lycan, 1996); and complex interplay of cortico-thalamic feedback systems (e.g., Crick, 1995).

There is significant evidence to make relevant each of these contentions, and the proffered explanations often overlap. For instance, the “working memory” hypothesis is attractive because our human consciousness seems clearly smeared out in time (there is no such thing, literally, as “what I am conscious of at this *point* in time”). What we can keep consciously in mind “at any moment” is limited to what is sustainable in our working memory, and though working memory requires a confluence of prefrontal lobe activities, these activities resonate neuronally with those of relevant sensory activities (e.g., occipital lobe activities when visual information is at stake), semantic memory activities (temporal lobe), “emotional systems” activity (including the amygdala, along with its connections), and so on—all of which would qualify as involving widespread availability of information. Since cortical systems work in conjunction with complex cortico-thalamic feedback mechanisms, such circuits are also part of the overall package.

Note, however, that while such speculations provide a type of grounding for our ordinary consciousness, not one of these explanations addresses *how* it is to occur. Either thesis A or thesis B can be equally fitted to the growing body of evidence associated with such hypotheses.

Conclusion

Not one of the scientifically motivated explanations currently available actually addresses *how* consciousness is to be caused. When theorists invoke one or another form of complex information processing in order to underpin a causal explanation, their efforts might well bring to mind the insightful comment made by Jackendorf (1983) years ago: “I find it every bit as incoherent to speak of conscious experience as a flow of information as to speak of it as a collection of neural firings” (p. 18).

As for more abstract theorists who wish to make further progress on this issue, they need to move beyond an exclusive enterprise of trying to find logical inconsistencies in rival theories and ask themselves in addition: How might my theory give rise to more concrete notions that will allow comparison with competing theories at the level of empirical observation and scientific experiment? The present paper would not be the appropriate vehicle in which to provide a detailed attempt in that direction, but one such effort can be found in Sullivan (1995, 2005, Ch 33).

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