Advanced Review

Attention and consciousness

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For the past three decades there has been a substantial amount of scientific evidence supporting the view that attention is necessary and sufficient for perceptual representations to become conscious (i.e., for there to be something that it is like to experience a representational perceptual state). This view, however, has been recently questioned on the basis of some alleged counterevidence. In this paper we survey some of the most important recent findings. In doing so, we have two primary goals. The first is descriptive: we provide a literature review for those seeking an understanding of the present debate. The second is editorial: we suggest that the evidence alleging dissociations between consciousness and attention is not decisive. Thus, this is an opinionated overview of the debate. By presenting our assessment, we hope to bring out both sides in the debate and to underscore that the issues here remain matters of intense controversy and ongoing investigation. ©
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ON THE CONCEPTS OF ATTENTION AND CONSCIOUSNESS

We claim that attention is necessary and sufficient for perceptual representations[a] to become conscious. We believe this claim finds support in empirical evidence. However, to properly evaluate such evidence, there is an important terminological issue that needs to be addressed first. When trying to define both 'attention' and 'consciousness', theorists lean toward one of two preferred strategies. The first one is to say that what is meant by 'attention' and 'consciousness' is what we *normally* mean by those terms. Call this *the commonsense approach*. The second strategy consists in stipulating a particular definition for these terms, a definition that may or may not coincide with their alleged typical usage. Call this *the stipulative approach*. We think both are problematic.

The main problem with the commonsense approach is that it presupposes a probably false claim: that people have a substantive and unambiguous notion of both attention and consciousness. To tap into the folk's concepts, philosophers typically latch onto the way people use their corresponding terms in the vernacular. For example, in a recent paper defending the commonsense approach, Christopher Mole[1] suggests that while people find it odd to say that one is not conscious of something one is paying attention to, it is not at all weird to say that one is conscious of some things one is not paying attention to. This implies that, according to commonsense, attention is sufficient for consciousness, but not necessary. We think this strategy for defending such substantive claims would not succeed. To see why, let us look at Mole's arguments a bit more closely.

Most philosophers defend their claims about the commonsense meaning of a term by simply stating their own intuitions. Impressively, Mole does some experimental philosophy. He tries to see what ordinary intuitions are, in case his own intuitions about usage are not representative, and he subjects his own intuitions to a hard test by presenting subjects with a case that seems, on the face of it, to be a counterexample to his theory: the propensity of a baby's cry to wake up her sleeping mother more readily than other noises. For, as he puts it: 'If the sleeping mother is not conscious of the cry, and if the selectivity demonstrated in the cry's waking her involves attention, then the case poses a serious problem for my claim that consciousness is necessary for attention'[1] (90). Mole conducts an informal survey to show that commonsense does not interpret this as a case of unconscious attention, but rather as a case of inattentive consciousness. In his survey, he informally asked 16 women to pick, among four possible answers—all involving a contrast judgment using

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only the terms 'attention' and 'consciousness'—which would be 'the most natural account of the fact that a baby's cry will wake a mother more readily than other sounds' ([1], 91). Most participants thought most natural to describe the case as 'The cry wakes the sleeping mother because, although she is not paying attention, she is conscious of it'. Mole takes this to show that the crying baby case is not a counterexample to the commonsensical view that consciousness is necessary for attention.

We think there is a more plausible interpretation of Mole's results. They may be read as showing that what is commonsensical is the view that there is a contrast between the sleeping mother's response to her baby's cry and her response to other noises, not that the contrast is, in fact, between attention and consciousness. In order to support this claim, we informally asked some of our non-philosopher friends to pick the most natural way of describing such a case, but now we used contrast judgments involving consciousness *and perception*, as opposed to consciousness and attention. Surprisingly, most of them suggested that the most natural way of describing the case was as 'The cry wakes the sleeping mother because, although she is not conscious of it, she can hear it'. Now commonsense seems to have it *not* as a case of consciousness but as a case of auditory perception. Are people contradicting themselves? Not necessarily. Our everyday concepts of consciousness and attention may be somewhat polysemous, and while in certain contexts they may be used in a certain way, in other contexts they may be used differently.[b] As a result, we do not think the commonsense approach can give us unproblematic definitions.

In light of this, one might be inclined to simply stipulate precisified definitions of 'consciousness' and 'attention'. But this strategy faces a problem of its own. Those who try to move beyond that suggestion that 'everyone knows what attention is' (cf.[2]) often replace the folk concept with idiosyncratic definitions that settle crucial questions by fiat rather than facilitating the process of scientific investigation and discovery. Take, for instance, B.F. Bradley's old view. He starts off saying that people have taken attention to be 'predominance in consciousness', and he cites J.S. Mill in support: 'The expression [attention] means that a sensation tends more or less strongly to exclude from consciousness all other sensations'. Thus, accordingly, Bradley decides to call attention 'a state which implies domination or chief tenancy of consciousness'[3] (1886, 22). In light of this definition, then, attention involves the activity of consciousness; indeed, it implies that there cannot be attention without consciousness, i.e., that consciousness is necessary for attention. Now contrast this definition with a newer one, this time from Mack and Rock[4] (, 25): '... "attention" is used to refer to the process that brings a stimulus to consciousness.' According to this definition, then, attention is required for consciousness, i.e., attention is necessary for consciousness. Both definitions leave little room for disconfirmation. Bradley has defined attention in a way that its occurrence is only possible if there is consciousness, while Mack and Rock have defined consciousness in a way that its occurrence is only possible if there is attention. Thus, if one is to adopt Bradley's, then every occurrence of attention is going to be, as a matter of definition, an occurrence of consciousness. However, if one takes Mack and Rock's, every occurrence of consciousness is going to be, as a matter of definition, an occurrence of attention. The trouble is that if one starts off with a definition that determines what the evidence is saying, finding out what the relation between consciousness and attention is will no longer be an empirical puzzle.[1] And if one thinks, as we do, that this is an empirical problem, one has to be very careful in defining the terms in such a way that neither of them implies analytically the other.

We think attention can be treated as a natural-kind term, with an empirically discovered essence. To begin with, the term can be given a provisional operational characterization in terms of the kinds of tasks people perform when asked to attend. Such tasks include focusing on an object, monitoring, tracking, scanning, and remaining vigilant. In some cases attention is focal, as when we track on object, and in other cases, it is diffuse, as when we monitor our surrounding. There are also more passive forms of attention, as when objects 'pop out' or 'capture' attention. Given this dazzling variety, one might think that attention has no unifying essence. We are open to that possibility. But we also think that many, if not all, of these psychological processes have something in common (see[5]). In each case, attending is a means by which information from the perceptual systems becomes available to working memory. Top–down, bottom–up, focal, or diffuse, availability to working memory is always involved. We think of the varieties of processes as different kinds of control structures that may guide a shared underlying mechanism of availability. The neurocomputational basis of that mechanism is still under investigation, but it presumably involves some change in cellular response that makes the difference between activity remaining in posterior perceptual pathways and potentially propagating forwards to lateral frontal areas, associated with short-term storage. Our current best guess, based on the empirical literature, involves

neural synchrony. The link between attention and neural synchrony has been extensively studied (e.g.,[6]), and details of the underlying mechanisms are starting to emerge. Attention involves an increase in interneurons, which send inhibitory signals to pyramidal cells, which encode sensory information.[7] When these inhibitory signals occur, it causes pyramidal cells to oscillate in synchrony (the oscillations may involve both local field potentials, associated with dendrites, and action potentials, associated with axons).[8] When sensory neurons oscillate in synchrony, they are able to send afferent signals forward in the brain for further processing and for encoding in working memory.[9] Different control structures, including top–down templates, as in visual search, and lateral competition, as in pop-out phenomena, determine which populations in interneurons become most active, and that, in turn, determine which of numerous neural populations corresponding to elements of the perceived scene will produce axon potentials that propagate forward to working memory structures.

ATTENTION IS SUFFICIENT AND NECESSARY FOR CONSCIOUSNESS: SOME EVIDENCE

Thus, understood, the claim that attention and consciousness share striking functional similarities finds ample neurophysiological, behavioral, and neuropsychological support. Using single cell recording in monkeys, Moran and Desimone[10] showed that attention gates visual processing by filtering out irrelevant information in the extrastriate cortex. This would explain for instance why some, but not all, visual information is consciously perceived: consciousness after all is selective, and attention would be the primary mechanism for this selection. They hypothesize further that this process may allow the creature to select and stabilize in memory relevant visual information. This hypothesis has been recently corroborated and advanced by studies using fMRI.[11–13] The correspondence between the selective nature of consciousness and the selective nature of attention lends strong prima facie support to the contention that a visual stimulus is consciously perceived when information in visual pathways is selected by attention and passed onto working memory.[14]

The functional correspondence between consciousness and attention finds further support in Posner,[15,16] who compares certain features of attention with some features of subjective conscious experience. Consider, for instance, the principle of relative amplification, according to which 'attention to sensory information amplifies brain areas used to process that modality' (p. 7399). Posner compares this feature of visual orienting with what he calls 'focal awareness': the kind of subjective recognition one has when a target 'pops out', as it were, in a search task. His suggestion is that attention's sensory amplification correlates quite nicely with focal awareness. The attention-to-memory story can also capture the difference between merely perceiving something consciously and noticing what that thing is. When we merely perceive something, attention makes the stimulus available to working memory by allowing perceptual representations to broadcast to working memory centers. When we notice the identity of a stimulus, working memory encoding actually takes place. Some stimuli are hard not to notice, such as a red dot in a field of blue dots (Posner, p. 7401). Once noticed, a stimulus can trigger responses in centers associated with executive control of attention, and this can exert top–down control on perceptual pathways, heightening sensitivity, and resulting in increased stimulus contrast, both at the neural and phenomenological levels.[17] We suspect that broadcasting, which is achieved by attentional modulation of perceptual representations, is the sufficient condition for conscious experience. In general, 'modulation' refers to a process that permits the occurrence of a certain kind of outcome, given a particular sort of input. Consequently, by 'attentional modulation' we mean to refer to the process, whatever it may be, that allows information to propagate from sensory cortices into working memory. This implies that perceptual information would not be accessible to working memory unless it is modulated by attention. The exact nature of these processes is a matter of empirical inquiry beyond the scope of this review, but the speculations at the end of section on *On the concepts of attention and consciousness* indicate one possibility.

So far we have been suggesting that there are striking functional similarities between consciousness and attention (e.g., selection, focus, a broadcasting/encoding distinction, bottom–up capture, and top–down intensification). In addition, there is a powerful behavioral evidence that consciousness comes and goes with attention. Work on attentional blink[18] shows that when looking for two stimuli in a rapid series, the first captures our attention, and that results in a brief interval in which we fail to detect the second stimulus. Work on change blindness[4] shows that when attention is consumed by one task—comparing the length of intersecting lines—people often fail to perceive foveally presented words and shapes. Subjects are often at chance at guessing whether such an object was presented, let alone its identity. That suggests attention is necessary for consciousness. Interestingly,

words and objects that capture attention (such as our own names or a smiley face) are perceived under these conditions. That suggests attention is sufficient for consciousness; when attention is captured invisible stimuli become visible.

One final piece of behavioral evidence comes from the work on change blindness. On the face of it, change blindness involves neither attention nor consciousness, in the usual sense of the terms. In change blindness, subjects fail to notice when an image changes, but they are conscious of—i.e., they have qualitative visual experiences of—the image both before and after the change. Indeed, subjects may even experience the feature that changes, without noticing that it changes. Noticing that something has changed is, in this sense, a metacognitive judgment about a difference between two consecutive experiences. And the key to making such a judgment seems to be memory, not attention: one has to temporarily store a particular detail to notice that it has undergone a change. But we think there is evidence that attention plays a role, and that noticing is not merely a metacognitive judgment, but it is rather a judgment brought on by a specific conscious experience. When one explicitly notices a change, it is because one has consciously experienced the transformation. We think that one can experience transformations because consciousness has temporal breadth. We experience not a sequence of still images, but dynamic events, including events of change. Furthermore, empirical evidence suggests that changes are consciously experienced only when one attends to the portion of an image that undergoes the change, which is just what our theory would predict. For example, Rensink, O'Regan, and Clark[19] found that change blindness occurred when they used a visual flicker to cause subjects to saccade away from the changing feature. This was true even when the images were presented for relatively long durations, suggesting that detection of change is not simply a matter of storing two images and comparing them, but rather involves attending to the right spot at the moment of the change. They also found that introduction of prior verbal cues eliminated or greatly reduced change blindness even in cases where the change took place in an area of the image that was peripheral. Attention seems to facilitate change detection; so, without it, changes go unexperienced, and, hence, unnoticed.

In sum, attention and consciousness function in strikingly similar ways, and one comes and goes with the other. That strongly suggests that perceptual representations are conscious when and only when we attend. We think this should be taken as a provisional hypothesis, subject to further empirical testing and refinement. As stated here, the hypothesis does not specify whether the link between consciousness and attention is *causal* or *constitutive*. If the link is causal, consciousness is a process separate from attention but attention is required to bring that process about or to enable it to occur. If the link is constitutive, the psychological or neural correlate of attention is identical to the neural correlate of consciousness. We do not think the data adduced above can decide between these options, but we do think these data suggest that attention is necessary and sufficient for consciousness. If consciousness comes and goes with attention under all experimental conditions, this suggests that human beings cannot be conscious in the absence of attention or unconscious when attention is applied.

This conjecture about necessity and sufficiency has been challenged recently in a number of ways. We will now offer an opinionated review of those challenges.

AGAINST EVIDENCE THAT ATTENTION IS NOT SUFFICIENT FOR CONSCIOUSNESS

One body of research attempts to break the link between consciousness and attention by showing that attention can occur when consciousness is absent. Consider, first, a study by Kentridge et al.[20] on G.Y., who suffers from blindsight. In a series of trials, G.Y. was asked to indicate whether a target had been presented somewhere in his blind field. On some trials a cue was presented in the blind field just before the target, which either accurately or inaccurately forecast the target location. When the cue was accurate, G.Y. was faster and made fewer errors. The authors conclude that he is attending in his blind field, and thus attention can occur without awareness.

To address this study, we need to refine our hypothesis. Let us distinguish between spatial attention (attention to a region of space) and attentional modulation of perceptual representations. We think consciousness involves the latter, not the former. When we say that attention is necessary and sufficient for making a representation conscious, we mean that consciousness arises when and only when a perceptual representation of some thing (a color, shape, object, movement, and so on) is modulated by attention. A shift of attention to a region of unoccupied space, where such spaces are possible, would not result in a conscious visual percept on the story we are presented. Spatial maps and stored records of spatial locations seem to involve the dorsal stream, which is believed to operate unconsciously.[21] This is not to say we cannot experience space. Normally, when we

attend to a region of space, whatever is in that region is consciously experienced, and we experience these objects as they are spatially configured. The ventral stream can represent objects in space and their relative locations. In cases of spatial cueing, we think there is typically a two-stage process that ensues. We attend to a region of space, and then, if anything is visible in that space, that thing gets visually represented and modulated by attention. But, in the study under consideration, this second stage does not occur. The cue causes G.Y. to attend to a region of space. But, because he has a lesion in his primary visual cortex, he cannot form a good representation of objects presented there. He must represent objects using subcortical and dorsal visual resources that are not modulated by attention. Why, then, does the spatial cue facilitate performance? Here there are three compatible answers. First, attending to a region of space may lower signal-detection thresholds for stimuli presented subsequently in that region; on this explanation, the stimulus representation would not itself come under attentional modulation, but the cells with receptive fields in the area occupied by the stimulus would be more likely to fire in response to the stimulus. Second, the spatial attention may cause receptive fields in the region to expand, which would increase the neural resources available for the subsequently presented target. Third, spatial attention may prime G.Y. for behavior responses in the attended region, including verbal responses to stimuli presented consciously or unconsciously. All these are compatible with the hypothesis we are defending. We think that, when an object is attended, its neural representation fires in a distinctive way (perhaps at a specific spiking or with greater temporal integration), which is necessary and sufficient for making the object representation conscious. There is no reason to think there are such representations in G.Y., because of his brain injury.

More recently, Kentridge, Nijboer, and Heywood[22] tried to show that the effect observed with G.Y. actually generalizes to normal subjects. They use a technique called metacontrast masking, in which a briefly flashed disk is followed by a ring; the ring prevents the disk from being experienced, even though the ring does not cover the region containing the disk. Kentridge et al. combine this with a Posner-style cueing technique: before the disk, participants see an arrow that is either congruent with the location of the disk or not. They find that disks are capable of priming performance on ring detection when disk and ring are of the same color (people detect rings faster when preceded by an unconscious disk of the same color), but only when the disk is preceded by a congruent cue. It looks like the cue is attentionally enhancing a stimulus that is not consciously experienced.

The problem here is very much like the problem with the G.Y. study. The Posner arrow draws attention to a region of space. That may lower signal-detection thresholds there, expand receptive fields, and potentiate behavioral responses, but there is no reason to think that a cue presented prior to the disk actually results in an attentionally modulated representation of that disk. Indeed, there is good reason to think that it is not what happens. The prevailing wisdom on metacontrast masking is that the mask (in this case, the ring) draws attention away from the object that it conceals.[23] (Indeed, this entire phenomenon seems to be an evidence for our thesis that attention is necessary for consciousness.) When attention is drawn to a region that contains a masked object, it may facilitate performance, but not by allocating attention to that object. The claim that attention is sufficient for consciousness can be challenged only by showing a case where an object representation is modulated by attention without being consciously experienced. That is not shown in these studies.

From this perspective, another recent study provides a more powerful challenge. Jiang et al.[24] used an interocular suppression paradigm with healthy subjects. In one eye, each subject saw a scrambled display in one location and a nude in the other; in the other eye, they saw two high-contrast scrambled displays in both of those locations. The high-contrast displays presented to the second eye masked the displays in the first eye, including the nude. But the unseen nude captured attention, as measured by (gender- and orientation-specific) facilitated target detection in the location where the nude had been. Unlike the Kentridge study, attention is not simply drawn to a region of space prior to stimulus onset; rather, an object—the nude—is capturing attention. This suggests that subjects can have an attended object representation in the absence of consciousness.

There is, however, another interpretation. Even though the object captures attention, the attention may be spatial. Normally a nude picture would elicit an attentionally modulated representation, but, in this case, the picture is masked. So it may be that the representation captures spatial attention, but fails to become modulated by attention itself. This is consistent with other studies, which show that unseen objects in interocular suppression paradigms produced increased activation in the spatially-sensitive dorsal stream, but not in the object-identity-sensitive ventral stream.[25]

In sum, we have found no conclusive evidence for attentionally modulated object representations in the

absence of consciousness. Attention may be sufficient for making perceptual representations conscious, even if spatial attention can occur unconsciously.

AGAINST EVIDENCE THAT ATTENTION IS NOT NECESSARY FOR CONSCIOUSNESS

There are a few empirical attempts to falsify the claim that attention is necessary for consciousness. Here we argue against three prominent ones. First, Koivisto, Revonsuo, and their collaborators have tried to show that we visually experience more than we attend to in a series of event-related potential (ERP) studies (see[26,27]). These studies build on early work that has identified electrical patterns of the scalp associated with the electrophysiological correlates of conscious awareness, on the one hand, and selective attention, on the other. *Visual awareness negativity* (VAN) is defined as the earliest electrophysiological correlate for subjective awareness of a stimulus, and it increases negativity at posterior sites peaking around 200 ms following stimulus onset. It has been shown to arise, e.g., when a masked stimulus is presented long enough to be detected.[28] *Selection negativity* (SN) is associated with the selection of a target or stimulus dimension when subjects are instructed to attend to one thing at the exclusion of another.[29] Koisvisto and Revensuo wondered whether VAN and SN correspond to the same process. To answer this question, they presented subjects with masked letters in different positions; so they could simultaneously measure degree of visibility (dependent on masking) and selection (dependent on letter or position). The results were quite interesting. They found that VAN initially arises earlier than SN and independent of the selection requirements of the task. Later VAN responses may interact with selection, but, early on, it seems quite independent, suggesting that conscious awareness does not depend on attention.

We think the conclusion they reach is too hasty. First of all, the results only show that VAN starts off before SN, but it says nothing as to whether VAN alone can suffice for conscious awareness. It is possible that consciousness involves a two-stage process: first a stimulus has to be represented above a threshold of detectability, which means there must be a representation that lasts long enough to avoid disruption by a mask. Then, once detectable, a stimulus is consciously detected when attention is allocated to it. In backwards masking, the first condition is not met, and, in inattentional blindness studies, the second is not met. If this two-stage picture is right, then it is possible that early VAN corresponds to detectability, but not detection. Second of all, even if we grant that VAN is a measure of awareness, we need not grant that SN is a measure of attention in the sense that is relevant to our hypothesis. SN is a measure of selection. It occurs when one stimulus is focused on rather than another. But, when this occurs, the neglected stimulus is not unattended. It is just allocated less attention than the selected stimulus. If it were unattended, it would not be experienced at all; that is what studies of inattentional blindness establish. In these experiments under consideration, it is overwhelmingly likely that *some* attention is spread across the entire display, even though one stimulus is selected for further processing. Selection may be a measure of whether a stimulus actually gets *passed on to* working memory, but all the stimuli in the slow presentation condition are *available to* working memory. It is this availability that correlates with VAN. We think attention is required for availability, and selection is a further phenomenon that takes place within the attended field. On this interpretation, it is no surprise that 'unattended' but visible stimuli are associated with VAN. These stimuli are not really unattended; they are subject to modest levels of diffuse attention, and 'unselected'.

Let us turn now to a further line of research. Neuroscientist Victor Lamme ([30,31], but see also[32]) has put forth a very suggestive argument in support of the view that attention and awareness are different. It begins with the unquestionable fact that not all visual information is conscious. Some visual information never makes it to consciousness. If attention is the gating mechanism of consciousness, as we suggest, then unconscious visual information is *just* unattended visual information. But it also seems unquestionable that some information simply cannot be conscious, even when attended (e.g. non-dominant patterns during perceptual rivalry). How can we distinguish, then, between unconscious stimuli that are merely unattended and purely unconscious ones? Lamme judges that, since the distinction between attention and consciousness would not do, we find ourselves in need of postulating some other mechanism to mark the distinction between stimuli that are unconscious because unattended and stimuli that are unconscious regardless. A more parsimonious explanation, according to Lamme, would be to mark an early distinction between conscious and unconscious inputs, and then an independent stage where attention selects between attended and unattended stimuli. On this view, attention does not determine whether certain information reaches consciousness, but rather whether certain conscious information is *reported*.

To support his view, he conducted the following change blindness experiment. Subjects were presented,

for 500 ms, with a stimulus consisting of multiple items arranged in a circle. Then a gray screen was displayed for 200–1500 ms, after which the same array as in stimulus 1 was presented, except that in this one an item was changed (stimulus 2). The changed item was cued with an orange bar, and subjects were asked whether the cued item had changed or not. Subjects perform poorly (60% correct). But when the item was cued in advance, during the display of stimulus 1, subjects performed quite well (100%). Interestingly, when the cue was shown alone in the gray screen that appeared after stimulus 1, subjects performed almost as good as they did when the cue was presented during stimulus 1 (88%). This suggests that all of the items in stimulus 1 are conscious, and remain in consciousness even after the stimulus is removed, until they are overwritten by stimulus 2. The cue causes us to attend to one item, but importantly, any item can be cued even after the original display is removed. That suggests that each item is conscious before it is cued, and, thus, attention is not necessary for consciousness.

Though suggestive, we think the argument can be blocked. First, as we just noted, Lamme thinks the figures in his display are all conscious even though they are not all attended (because each can be reported even when cued only after they have been taken away). We think it is possible to interpret Lamme's study in a way consistent with the idea that attention is necessary for consciousness. One could say, for instance, that when the stimulus array is presented, attention is covertly distributed across the whole display, regardless of whether any item has been cued. But attention does not guarantee encoding in working memory; it simply makes perceptual representations available for encoding. The post-stimulus cue can result in encoding, because each array item leaves a brief trace in iconic memory. The fact that most uncued items cannot be recalled does not entail that they were not attended. It is rather explained by a sort of 'amnesic' effect: the loss of the visual memory. By the time we try to encode what we have made available to working memory through attention, the second stimulus has overwritten the visual trace, and there is no perceptual representation left to encode. If this interpretation is correct, then what seems to be required for us to consciously remember the first stimulus is that attention can move it into working memory. If attention does not get to it quick enough, and another stimulus overwrites the first one, then you fail to notice the change.

Lamme's reason for denying that attention is necessary is driven by his positive views about the neural correlates of consciousness. He thinks that phenomenally conscious vision results when there is re-entry of visual signals into V1 after they have been processed in higher visual areas. Lamme believes that re-entry occurs without attention, and he compares this process to phenomenal consciousness without access consciousness.[33] Attention, which involves an interaction between sensory processing and memory, is not the correlate of phenomenal consciousness, just access consciousness. In support of Lamme, there is indeed evidence that re-entry occurs during visual consciousness, and that consciousness can be disrupted when re-entry is disrupted. But these results are consistent with another interpretation. We think re-entrant activity is just attention going back into early visual areas in order to facilitate propagation forward into working memory. If we are right, and if attention is necessary for consciousness, then it is not surprising that disrupting re-entry can disrupt conscious experience. This explanation is more economical than Lamme's. His' needs two processes (one for consciousness and another for attention), whereas we see attention and consciousness as a single process, which tends to result in re-entry, but does not have to. Of course, this alternative would need to be empirically tested. There is an evidence linking re-entry to attention[34,35,] but a decisive reply to Lamme would show that consciousness can arise even in the absence of re-entry.[c] That is hard to demonstrate, because the best method for prevent re-entry is to follow one stimulus by another in rapid succession, but the second stimulus effectively masks the first. A proper test requires sustained response in higher visual areas without V1. For this we might look to patient populations. For example, individuals with blindsight have visual experiences in their blind fields under certain circumstances even in the absence of V1. Future work is needed to see whether re-entry can be dissociated from consciousness in healthy individuals.

There is one more argument for the claim that attention is not necessary for consciousness that we would like to consider. Koch and Tsuchiya[36] mention that we have awareness of the 'the gist' of our surrounding environment when we are not paying attention to it. As we saw, people can make discriminations when an image has been presented for only 30 ms, which is very little time for focused attention to act on it. People can also recognize faces when they are simultaneously carrying out an attentionally demanding task. According to Koch and Tsuchiya, this seems to show that we can have conscious awareness 'in the near absence of attention'. But these results are not compelling. For one thing, the near absence of attention is not the same as the absence of attention. In face recognition, we have

reason to believe some attention is allocated, since faces tend to be attention lures. Indeed, if there were no attention here, we would probably fail to detect or recognize the faces, since that is precisely what studies of inattentional blindness show. In the cases of gist extraction, we also have no reason to think attention is absent. It may be that diminished attention attenuates the amount of detail in a visual representation that can be sent forward to working memory, because of what the gist is perceived and no more. So, in fact, such findings are predicted by the view that attention is necessary for awareness. When it's nearly absent, we are aware of far less than when it is more fully deployed.

CONCLUSION

In this review we have attempted two things. First, we offered a survey of research relating attention to consciousness, beginning with studies that try to show that attention is necessary or sufficient for consciousness, followed by studies that try to establish a dissociation. Thus, the current literature offers conflicting assessments of the relation. Second, to escape this stalemate, we offered some reasons for thinking that the dissociation studies are inconclusive. If we are right, it remains plausible that attention plays an essential role in consciousness; indeed, the neural correlates of consciousness could prove to be identical with the neural processes underlying attentional modulation of perceptual representations. Future research will no doubt settle this ongoing debate.

NOTES

[a]Throughout, we will be focusing on representations of visual objects and their features. We do, however, think that attention can be allocated to anything we can consciously experience, including pains, emotions, and so on.

[b]A further study conducted by the first author suggests that this issue is actually even more complex than space allow us to explore here.[37]

[c]Using ERP Woldorff et al.[35] report having found larger magnetic responses at very early latencies (P20-50 and N100) evoked by the activity of the auditory cortex ipsilateral to the ear where the tone that the subjects were attending to was elicited. This finding suggests that focusing attention on a particular incoming aural stimulus can modulate its sensory processing at very early stages in the auditory cortex, well before the information reaches high cortical stages, where full-fledged perceptual analysis is supposed to occur. Similar results have been found regarding visual-spatial selective attention. When asked to attend to a particular location, subjects showed an 'increased early positively over occipital cortex contralateral to the direction of attention (80–130 ms) that is evoked by all stimuli presented to the attended location'. This early attentional increment is known as the 'P1 effect', and it suggests that some early selection is done at the dorsal occipital cortex, a low-level sensory area. However, in this study, Woldorff and colleagues reported a further, striking result. Combining ERP and positron emission tomography (PET), they managed to delineate the temporal sequence of brain activations during visual attention performance. And in doing so they found that besides the P1 effect evoked by the contralateral occipital cortex there was also an enhanced negative wave (N2), peaking between 240 and 280 ms (around 140 ms after P1), evoked at essentially the same contralateral occipital scalp location. This finding suggests the re-entrance of attention-related activity in the same low-level sensory area of the visual cortex.

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