Attentional Networks and the Semantics of Consciousness[1]

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ABSTRACT

The term consciousness is an important one in the vernacular of the western literature in many fields. It is no wonder that scientists have assumed that consciousness will be found as a component of the human brain and that we will come to understand its neural basis. However, there is rather little in common between consciouness as the neurologist would use it to diagnose the vegetative state, how the feminist would use it to support raising male consciousness of the economic plight of women and as the philosopher would use it when defining the really hard question of the subjective state of awareness induced by sensory qualities. When faced with this kind of problem it is usual to subdivide the term into more manageable perhaps partly operational definitions. Three meanings that capture aspects of consciousness are: (1) the neurology of the state of mind allowing coherent orientation to time and place (2) the selection of sensory or memorial information for awareness and (3) the voluntary control over overt responses. In each of these cases the mechanisms of consciousness overlap with attentional networks that have been explored with the methods of cognitive neuroscience. In this paper we explore the overlap and discuss how to exploit the growing knowledge of attentional networks to constrain ideas of consciousness.

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Introduction

A previous paper on this topic (Posner, 1994) argued that the mechanisms of attention formed the basis for an understanding of consciousness. While I still believe this to be true as a general summary the intervening years have provided evidence of dissociations between brain networks involved in attention and aspects of consciousness.

In this paper I first summarize the relation of attention and consciousness (i) and illustrate how the study of attentional networks might help illuminate dissociations (ii). Because attention involves different brain networks (Posner & Petersen, 1990, Posner & Rothbart, 2007) and because consciousness has a wide variety of definitions it is necessary to illustrate their constraints and inter-relations rather than provide a single unified account. I try to do this by dealing first with the conscious state, second with consciousness of sensory qualities and finally with volition. It turns out that each of these definitions is predominantly associated with a different attentional network. I then turn more briefly to the issue of the most important unsolved questions (iii) and the methods (iv) that their solution might require.

State

Within neurology consciousness often refers to a brain state in which the person is capable of responding to external events and relates them to the self (Posner, Sapir, Schiff & Plum, 2007). This state is closely associated with the concept of arousal and to the diurnal cycle of sleep and wake. Clearly during sleep we are unable to respond appropriately to many external events and patients in coma due to lesions of the arousal system are also unable to determine issues such as their current location or the time of day or year.

In my view it is possible to study the mechanisms underlying the conscious state by varying it when the person is awake. The most convenient way to do this is to provide a warning signal that a target is about to occur but it can also be done by allowing a person to participate in a long and somewhat dull task and measure their vigilance over time (Posner & Petersen, 1990: Posner, in press). These studies have revealed the importance of the brain's norepinepherine system arising in the brain stem locus coeruleus and involving both frontal and parietal brain areas. In the posterior part of the brain this system influences more dorsal areas involved in attention and has little direct input into strictly sensory areas of vision. The right cerebral hemisphere is most involved in maintaining the alert state over long periods of time (tonic alertness), while the left cerebral hemisphere responds more to phasic changes induced by warnings. Support for this link between the mechanisms of alertness and the state consciousness comes from a recent finding showing that the conscious state of rats can be eliminated by injecting anesthetic into the midpontine tegmental system which has close connections to the locus coeruleus, the anterior cingulate and other frontal structures (Sukhotinsky, Zalkind, Lu, Hopkins, Saper & Devor, 2007).

The alert state provides the background in which consciousness can be directed to external events or voluntarily to thoughts. Even in the absence of the alert state we can be conscious of internal events as in dreams. The obvious difference between our consciousness of external events and our voluntary scans of memory and dreams show the importance of these attentional mechanisms in our conscious experience. The mechanism of alertness clearly influences conscious experience although in all states of alertness some form of consciousness is possible.

Sensory Awareness

An important distinction in studies of awareness (Iwasaki, 1993) is between general knowledge of our environment (ambient awareness) and detailed focal knowledge of a scene (focal awareness). We generally believe that we have full conscious awareness of our environment, even when our focal attention is upon our own internal thoughts. Experimental studies (Rensink, O'Regan & Clark, 1997), show us how much this opinion is in error. In the study of "change blindness" when cues that normally lead to a shift of attention are suppressed, we have only a small focus for which we have full knowledge and even major semantic changes in the remainder of the environment are not reported.

Change blindness is closely related to studies of visual search which have been prominent in the field of attention and is known to involve an interaction between information in the ventral visual pathway about the object identity and information in the dorsal visual pathway that controls orienting to sensory information (for a review see Driver, Eimer, Macaluso & van Velzen, 2004). Visual search tasks have been important for examining what constraints attention provides to the nature of our awareness of a target event. There is clear evidence that attention to a visual event increases the brain activity associated with it. Most evidence arises from studies using event related electrical potentials with visual stimuli and these have clearly shown that early sensory components of the visual evoked potential P1 and N2 (80-150 millisec) are enlarged by the presence of attention (Hillyard, 2004).

If attention can serve to constrain conscious experience its presence should enhance the luminance of a visual target and lead to the judgment that it is brighter than would otherwise been reported. The increased P1 found in the EEG studies would support this prediction. However, this apparently does not occur, at least for stimuli that are sufficiently bright to be conscious. In an extensive series of experiments Prinzmetal and associates (1997) have shown that being able to pay attention to a stimulus or direct attention to a stimulus location improves the variability of judgments about luminance or other stimulus dimensions but does not brighten it. This suggests an important dissociation between luminance increases and attention on subjective experience even when they influence the same component of the scalp recorded ERP. While it is possible that a previously unseen stimulus will become conscious when attended, it appears generally that top down influence on sensory systems can usually be distinguished from sensory changes even when they involve the same general neural systems.

A recent review of the literature (Koch & Tsuchiya, 2007) argued that attention and consciousness of external stimuli are two distinct brain processes. They produce a four fold table that distinguishes between non conscious and conscious processes and between attended and non attended. They argue that all four possibilities are possible. Two of them: attention without consciousness and consciousness without attention dissociate the two. For example, they argue that the pop out effect in visual search, or the ability to provide the gist of a scene are examples of conscious processes that can occur without attention. This idea seems to confuse orienting of attention to items in the display, which is often not reported, with focal attention involved in processing the target.

They also argue that attention is required for priming, visual search or thought but these things may not give rise to consciousness. The issue of whether attention is needed for priming illustrates how attention is not unified. Priming can occur even when no attention is allocated to the meaning of the prime. For example, a bias to treat the word "palm" as a tree does not eliminate the priming of finger at least for a brief moment (Marcel, 1983) . This shows that attention in one sense is not needed for priming. However, if attention is allocated to a letter the ability of the word of which the letter is a part to improve processing of related words (semantic priming) is reduced or eliminated. Moreover, the influence of a prime appears to depend on the person allocating attention at the proper time and place (Dehaene 2004), even if unaware that a word was presented. As the exact mechanisms of priming are better understood we may learn more about how the form of attention involved relates to the experience.

Most striking is evidence they cite from Olivers & Nieuwenhuis (2005), who found that observers report the second of two rapidly presented stimuli more often when they are distracted by an another task than when they are concentrated on the display. This shows that a reduction of attention can be accompanied by an increase in awareness of the target. This striking demonstration may reflect different attentional networks. The attentional blink arises because while the person concentrates on target 1 and as a consequence target 1 and target 2 are not perceived as separate events. The dramatic dissociation between awareness of a target and the availability of attention provides evidence that the two phenomena are not exactly the same. This dissociation may arise because there is a specific inhibition to processing a second target when it is similar to a first target which is still being attended. If concentration on the first target is reduced by a second task the inhibition may be released. In visual search orienting to a location slows reorienting (inhibition of return). If the second target is inhibited when the first is being processed, the reported dissociation may not indicate that attention is distinct from awareness, but instead that attention may be distinct from performance.

Volition

Focal attention to the target of a visual search appears to involve a brain network that includes the anterior cingulate and lateral prefrontal areas (Posner & Rothbart, 2007). Humans have a conviction of conscious control that allows us to regulate our thoughts, feelings and behaviors in accord with our goals and people believe that voluntary conscious choice guides at least a part of the action we take. These beliefs have been studied under various names in different fields of psychology. In cognition, cognitive control is the usual name for the voluntary exercise of intentions, while in developmental psychology many of the same issues are studied under the name self-regulation (Posner, Rothbart Sheese & Tang, 2007).

Imaging studies suggest that whenever we bring to mind information, whether extracted from sensory input or from memory, we activate the executive attention network. This may be because focal attention is voluntarily switched to the target information. Thus moving attention to a target in order to bring it fully to mind is one type of voluntary response. As such it would require the executive attention network irrespective of the source of information.

We started out this paper with the traditional distinction between awareness and control as components of consciousness. However, one form of awareness, focal awareness, appears to involve the same underlying mechanism as involved in control. In this sense even though some forms of consciousness (e.g. ambient awareness) may have diverse sources within sensory specific cortex, there is also a degree of unity of the underlying mechanism involved in some aspects of consciousness (e.g. focal awareness and voluntary control). The distinction between focal and ambient factors in consciousness has been made before (Iwasaki, 1993) and it may help to clarify the sense of awareness that can be present even when detailed accounts of the scene are not possible as in change blindness (Rensink, et al, 1997).

Issues awaiting solution

The study of attention has made great strides in the last several years. It has been possible to combine imaging, genetics and even cellular studies in humans, monkeys and rodents to examine aspects of networks involved in the various functions of attention (Posner & Rothbart 2007).

One way to proceed involves continuing the development of models of attention. We can then determine the constraints upon various definitions of consciousness they might provide. We need also to keep in mind that in the end these constraints may not be sufficient to entirely answer the many issues related to consciousness. It is important to realize that mapping of attention and consciousness is not one to one, but rather a mapping that involves several attentional networks in addition to the several meanings of consciousness.

Some additional avenues for exploring this relationship may involve studies of

altered states which change attention and may also vary the quality of our conscious experience such as those induced by brain injury, hypnotism, drugs or meditation. The study of each of these states has been enhanced by the use of neuroimaging both of grey matter areas and of the connectivity between these areas. Real time analysis of this connectivity will probably be crucial to the full specification of the networks of attention and of consciousness (Posner, Sheese, Odulas & Tang, 2006).

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