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What Is Attended In Spatial Attention?

Abstract: Mole's (2008 [this issue]) argument that consciousness is a necessary concomitant of attention rests on the question of what is being attended in spatial attention. His answer is space. Some authors, including ourselves, claim that the fact that the processing of unseen objects can be modulated by spatial attention (e.g. Kentridge et al., 1999; 2004; 2008; Marzouki et al., 2007; Sumner et al., 2006) demonstrates that visual attention is not a sufficient precondition for visual awareness. Mole, however, contends that as space, rather than any object that might occupy that space, is what is being attended, these experiments do not constitute evidence for a dissociation between attention and consciousness. We disagree. To understand the source of this disagreement we need to understand the various processes encompassed by the term 'attention' and to consider experimental evidence illustrating how these processes operate. We review evidence that spatial attention can be deployed with the specific goal of determining the properties of objects occupying the attended region of space. One might, for example, attend to a location with the goal of determining the colour of objects occupying that space as efficiently as possible. Mole's assumption that all that is attended in spatial attention is space is not consistent with this evidence. We conclude that attention can be directed at objects by mechanisms of so-called 'spatial attention' without those objects necessarily eliciting conscious visual experience and hence that attention is not a sufficient precondition for visual awareness.

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In his *Principles of Psychology* William James (1890) noted that attention has two key components. Attention, he wrote, ‘implies withdrawal from some things in order to deal effectively with others’. Attention, then, involves a process of selection (withdrawal of processing from parts of the world in favour of other parts) and enhancement (the selective concentration of resources results in enhanced processing of the object of attention). In visual attention selection might be based on all sorts of properties, for example colour (‘look out for red things’), shape (‘look out for triangles’) or spatial location (‘look out for things on your left’). The properties of an object whose processing is enhanced might again be many and varied and, in principle, can be quite specific and need not be the same as those upon which selection is based. One might attend to red things with the aim of determining whether they are triangles. So the basis of selection and features whose processing are enhanced could potentially differ. One thing that seems clear before we even consider empirical evidence regarding this question is that in spatial attention they surely *must* differ — selectively attending to specific spatial locations would have no function if all that could be enhanced was our the perception of empty space. Selecting a location for attention only seems sensible if we do so in order to facilitate processing of some properties of objects which might be presented at that location. If this is the case then it seems reasonable to assert that, as it is one of the properties of an object’s processing that has been amplified, that objects in the attended location are themselves being attended.

Taking the lead from James once again, many authors have suggested that there is an intimate relationship between attention and awareness such that visual events can only elicit consciousness experience if they are attended. In 1999 we tested this assumption in the blindsight patient GY (Kentridge *et al.*, 1999). Blindsight is a neurological condition in which, as a consequence of damage to primary visual cortex, patients are rendered blind in part or all of their visual field. Such patients can, however, perform a variety of visual tasks with remarkable accuracy despite denying that they have any experience of the visual stimuli to which they are responding (Weiskrantz, 1986). We used Posner’s (1980) classic attentional cueing paradigm in which a cue preceding the presentation of a visual target provides information about the target’s likely location. Any difference in the speed or accuracy of response to the target between trials where the cue correctly predicted its location (i.e. it is a valid cue) and trials where the cue was misleading (an invalid cue) is evidence of spatially selective attention. Despite denying that he has any experience of the

targets in our experiment, we nevertheless found significant differences between GY's performance on valid and invalidly cued trials. We have since replicated this finding in normal observers (Kentridge *et al.*, 2008).

In his recent paper Mole (2008 [this issue]) suggests that we were incorrect to conclude that we had demonstrated dissociation between attention and awareness. Mole's argument is that, as we used spatial cues, our subjects were attending to space, not to the objects that occupied that space. Although we demonstrated an effect of cue validity on our subjects' performance, he argues that they were not actually attending to these stimuli, they were just attending to the space they occupied. As such, absence of awareness and attention apply to different entities, stimuli and space respectively, and so no dissociation has been demonstrated in a single entity. Mole crystallizes the question of whether attention necessarily leads to awareness in the following statement:

α : For all persons and all things, if the person is attending to the thing then the person is conscious of that thing (Mole, 2008, p.100).

Using a circle as an example of a stimulus, he suggests that demonstrations of spatially selective attention where the stimulus at the attended location remains unseen do not constitute a counterexample to this statement:

because the second conjunct is not satisfied — the facilitative effect of the cue can be understood as a consequence of the subject attending to the *location* in which the circle appears. There is no need to say that the blindsighter is attending to the circle itself (Mole, 2008, p.101).

The argument rests on the assumption that attending to a location is not part of the same process as attending to the properties of objects at that location — that is, that the basis of selection and the object of attentional enhancement cannot dissociate. There is, however, good evidence that selection and enhancement processes are independent. In other words that one can, for example, attend to a spatial location in order to identify the orientation of a line (as in Kentridge *et al.*, 2004). Is this true of the examples Mole uses?

Mole's example of attending to the blind-spot is a red herring. Since no signal from objects presented at the blind spot reaches the nervous system, the question of whether objects appearing in this particular, peculiar, region of attended space are themselves attended is meaningless.

In exploring common-sense understanding of attention Mole asks us to think about another example: a sleeping mother who wakes on

hearing her baby's cry although she remains undisturbed by other similar sounds. One issue this example raises which Mole does not consider is just what the mother is selectively attending to in order to hear her baby's cry. Logically, the basis of selection must be preattentively accessible. But this implies that the mother does not need to attend in order to discriminate the baby's cry and yet Mole argues that this is what she is attending to. Her attentional goal may indeed be detection of her baby's cry; she must, however, be selectively processing some kinds of sound which can be discriminated preattentively (e.g. high-pitched ones) in order to check whether they are baby's cries. Here then is a fine example of a situation in which we say that a person is attending to *x* while they are selecting on the basis of *y*. If the mother knows that her baby is in the room upstairs the basis of her selection may surely be spatial even though we still say she is attending to hear her baby's cries.

Are we just playing word games about what should and should not be subsumed by the term attention? Empirical evidence can be brought to bear on this issue. What is the evidence that spatial attention can be tuned to facilitate processing of specific properties of objects? Does the facilitation that occurs when selection is object-based differ from that following space-based selection?

Remington & Folk (2001) conducted an experiment which elegantly illustrates that spatial attention is deployed in order to facilitate the processing of specific properties of objects. Their subjects were presented with stimuli at four locations one of which was spatially cued. The stimuli varied in two dimensions (letter identity and orientation), only one of which was to be reported on any given experimental trial. One letter and orientation were reported with one response (e.g. pressing the left of two buttons for 'T' or for right sloping letters), another letter and orientation required the other response (e.g. a right button press for 'L' or left sloping letters). The dimension to be reported was indicated at the start of each trial. One of the four stimuli presented on each trial was red (the others were white). It was the property of the red stimulus on each trial stimulus that was to be reported. On one trial the subject might therefore be asked to report the orientation of the red letter. The letter's identity (whether it was a 'T' or an 'L') was irrelevant. On another trial report of the red letter's identity might be requested while its orientation should be ignored. This target letter could occur in the cued location or in one of the three uncued locations. The critical aspect of this design lies in the opportunity it gives the experimenters to determine which attributes of the visual stimulus undergo enhanced processing in the region of attended

space and which remain unaffected by selection — that is, processed in a uniformly distributed manner across space.

Consider a trial where the subject must report letter identity and the red target letter is a 'T'. The subject must press the left button. The subject's response speed is likely to be affected by the letters presented at other locations in the display. If one of the non-target letters is an 'L' which elicits a right button press response which is incompatible with that required to report the red target 'T' then the speed with which the 'T' is reported is slowed. Non-target letters which are neither 'L's nor 'T's produce no response incompatibility and reaction times to the target are faster. The dependence of this effect on attention can be measured by comparing trials in which the non-target response-incompatible item is presented at attended, as opposed to unattended, locations. There is a much larger effect of response incompatibility for letters at the attended location.

The crux of the experiment, however, lies in the effect of the task-irrelevant dimension. If the red target letter whose identity must be reported has an identity that requires one response and an orientation that requires the other then reaction time is slowed no matter where attention is directed. What though, is the effect of the task-irrelevant dimension at *non-target* locations? Recall that attention significantly affected the consequences of response-incompatibility in the task-relevant dimension. In the task-irrelevant dimension, however, it does no such thing. The effect of task-irrelevant response-incompatibility is just the same at attended and unattended non-target locations. Spatial attention is specifically facilitating processing of properties which are relevant to the task at hand.

What are 'task-relevant properties' properties of? Obviously they are properties of objects, not properties of space. It might make sense to believe that an object which occupies attended space is not, itself, attended if the facilitation engendered by spatial attention was non-specific, i.e. if all sensation in that region of space was amplified. We have, however, seen that spatial attention can be deployed in order to determine whether objects with a specific property are present. As the facilitation of processing in attended space only applies to objects with that specific property it does not make sense to us to argue that those objects are not being attended. Spatial attention must be for attending to objects. Indeed, at the physiological level, whether selection is based on the likely location of target objects or whether one is selecting objects on the basis of some visual property, the physiological indicators of enhanced processing are the same (McAdams & Maunsell, 2000).

In our recent experiments on the effect of attention on unseen stimuli our subjects' tasks were to report specific properties of objects. In Kentridge *et al.* (2004) the blindsight patient GY was asked to guess the orientation of a line. When his spatial attention was directed towards the location in which the cue appeared his reports of line orientation were faster and more accurate than when his attention was misdirected, even though he denied seeing the lines whose orientation he was reporting. In Kentridge *et al.* (2008) we rendered coloured stimuli invisible to normal subjects using masking. Our subjects never reported seeing the masked stimuli and could not distinguish trials on which masked stimuli were presented from those where there were no such stimuli. Again we were able to show that spatial attention affected the influence that these unseen stimuli had on subsequent conscious colour discriminations. In both of these experiments we feel there is no question that our subjects were attending to the objects occupying attended space.

The strength our position can be seen all the clearer if rather than challenge it, we take Mole's argument to its extreme, and suppose that spatial attention does nothing but enhance our representation of empty space. Imagine for example a creaking branch of a tree, that attracts our attention to the space around it and yet completely fails to help us detect a snake camouflaged along the length of the bark. When our attention is attracted to locations in space we may not know what objects occupy those locations; if attention did not selectively act to enhance the representation of important objects in that space it would clearly be of little value. We (Kentridge *et al.*, 1999; 2004; 2008) and others (Marzouki *et al.*, 2007; Sumner *et al.*, 2006) have established that this selective enhancement of an object's properties by spatial attention can occur without any conscious experience of those properties or their enhancement. This evidence provides some unintuitive insights of great value, both that attention can act without consciousness and that attention does not act as a simple gate-keeper to awareness.

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