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Metacognition and Awareness

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It is tempting to assume that metacognitive processes necessarily evoke awareness. We review a number of experiments in which cognitive schema have been shown to develop without awareness. Implicit learning of a novel schema may not involve metacognitive regulation per se. Substitution of one automatic process by another as a result of the inadequacy of the former as circumstances change does, however, clearly involve metacognitive and executive processes of error correction and schema selection. We describe a recently published study in which we serendipitously discovered that a blindsight subject could change the schema with which he processed cue information in orienting spatial attention task without reporting any awareness of this change, or of the cues and targets which respectively directed and were the object his attention.

In this paper we want to explore the relationship between metacognitive and executive regulatory processes and consciousness. There is nothing inherent in metacognitive regulation that demands consciousness. Metacognitive and executive processes serve to select and deploy methods for dealing with events and to assess the utility of those methods. The presence of a self-referential loop, a system which assesses its own performance and adapts accordingly, might tempt us to infer that such processes necessarily elicit awareness. Feedback loops are ubiquitous in biology and, of themselves, do not seem to be grounds for invoking consciousness. Perhaps the crucial property of metacognition is that this feedback loop, being a level removed from the interaction between perception and action, is not driven by differences between obtained and desired performance, but by differences between obtained and expected performance—it involves evaluation and adaptation of an internal model of our interaction with the world. Situations not encompassed by this model must be dealt with using default methods—automatic processes. Introspection suggests that automatic responses to events may occur without our awareness, whereas we are aware of voluntary responses.

As Posner, DiGirolamo, and Fernandez-Duque (1997) note, automatic processes are involuntary and not usually conscious. Simple logic demands that an automatic process is the default process automatically invoked in processing any given task at any particular time. When the default process we use to tackle a task changes, this change may involve either the construction of a new schema or the substitution of

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an existing schema as the default for that task. In either case the change in default process is a matter of metacognitive regulation. In their discussion of error detection and adjustment of response strategies Fernandez-Duque, Baird, and Posner (this issue) suggest that ''monitoring and *awareness* of the selected response are crucial for coherent and successful behavior.'' The italics are our own, added because we wish to discuss some recent evidence which indicates that awareness may not be necessary for, and may not necessarily accompany, changes in the automatic processing of a task.

Lambert and Sumich (1996) showed that spatial attention can be directed by an implicitly learned relationship between the semantic category of words which act as cues and the location of a subsequently presented target. Subjects learned, for example, that words for animate objects were likely to be followed by a target on the same side of the screen as the word was presented while inanimate object words were more likely to be followed by a target on the opposite side of the screen. Lambert and Sumich do not describe this orientation of attention as voluntary as their subjects were unaware of the word–location relationship they had learned. In two experiments attentional learning was only revealed through differences in subjects' reaction time to targets whose locations followed or deviated from the rule relating cue category and likely target location but not by an open-ended question regarding the nature of the cue–target relationship or by a forced choice test between the description of the rule actually used and a rule in which the role of animate and inanimate words was reversed. In a third experiment subjects' reaction-time performance was consistent with their answers to the forced choice question, but again, they claimed no explicit knowledge of the relationship they had learned. In a later series of experiments Lambert, Naikar, McLachlan, and Aitken (1999) showed that implicit learning of cue–target relationships could even take place when cues were presented below the subjects' threshold of awareness. They also showed that the characteristics of implicitly learned attentional control resemble reflexive orienting (e.g., the direction of attention to the location at which a cue appears) more than they do conscious voluntary control.

The studies of Lambert's group indicate that a new schema can be developed and become automatic without a person having explicit knowledge of the process. These studies may not, however, strictly involve metacognitive regulation. One could argue that the construction of a schema *ab initio* does not involve monitoring the utility of an existing schema. Some recent work of our own suggests that a failing automatic schema can be replaced without awareness of either the failure or the replacement.

Eminent psychologists since the time of James (1890) and Wundt (1912) have linked attention and consciousness in one way or another. Posner (1994) suggested that subjective experience is related to activity in the circuits mediating the executive, but not automatic, control of attention. Milner and Goodale (1996) have also suggested that attention may be necessary for consciousness; however, they distinguish between attention in the service of action, which they propose need not evoke awareness, and attention in the service of object identification, which they propose is linked to awareness. Mack and Rock (1998) describe a series of experiments in which direction of attention away from a particular location resulted in subjects being unaware of stimuli presented at that unattended location, again suggesting that attention was necessary for awareness. We chose to address the question of whether attention was

a sufficient, rather than necessary, condition for awareness (Kentridge, Heywood, & Weiskrantz, 1999). Our interest in this question was initiated by the observations of a subject who, during debriefing from one of our experiments (Kentridge, Weiskrantz, & Heywood, 1997), mentioned that he was attempting to direct his attention to a specific spatial location. This seemingly unremarkable comment was made extraordinary by the fact that the subject had blindsight—a condition in which visual awareness is absent or diminished in part of the visual field as a result of damage to primary visual cortex or the geniculostriate projection (see, e.g., Weiskrantz, 1997). Although blindsight subjects deny visual awareness, they nevertheless retain the ability to perform a variety of simple visual discriminations within their region of subjective blindness. We set out to discover whether visual attention could indeed be oriented by our blindsight subject within his blind field, whether the engagement of such attention required awareness, and whether attending to the location at which a target was presented necessarily gave rise to awareness of that target.

We measured the effect of cues indicating the likely location of stimuli on our blindsight subject G.Y.'s reaction time to those stimuli. The results indicated that G.Y. could direct attention to specific locations within his blind field when those locations were indicated by cues presented in a region of normal vision. More surprisingly, he was also responsive to cues presented within his blind field—his reaction times to stimuli he could not see could be speeded by cues he could not see. This ability even extended to situations where cues in his blind field indicated that stimuli were likely to appear at a second location, rather than directly indicating the likely stimulus location.

The ability to direct spatial attention is typically assessed by presenting a target preceded by a cue which may, or may not, indicate the correct location of the subsequent target (Posner, 1980). Valid cues produce more rapid responses to targets than misleading cues, which in turn may produce slower responses than a neutral condition. We adapted this method for use in blindsight and manipulated the likelihood that the subject had conscious experience of the cue. An auditory tone was preceded by a visual cue which signaled the likely target location. The subject's task was simply to guess as quickly as possible, using a manual button press, whether or not a visual target accompanied the presentation of the auditory tone. Reaction times were measured. On 50% of trials no target was presented. There were two possible target locations. On 68.75% of trials when a target was presented the (''valid'') cue correctly indicated the target location; on the remaining 31.25% the target appeared at the other location; i.e., it was preceded by an ''invalid'' cue. After he made his guess on each trial we asked G.Y. to make a second response indicating whether he had had any awareness of the target.

Our first experiment used arrows as cues, presented at fixation, a location outside G.Y.'s blind region, and hence fully visible to him. On each trial the arrow pointed in the direction of the more likely target location. G.Y. was quicker to detect targets when the cue accurately disclosed their location without being any less accurate at discriminating trials where a target was presented from those where it was absent. The difference between reaction times in the two cueing conditions must therefore be attributed to selective attention, as opposed to a trade-off between the speed and accuracy of judgments. We then went on to test the effectiveness of cues presented

in G.Y.'s blind field in directing attention. First, we used a design in which the cue was a pair of bars which bracketed one of two possible target locations. G.Y. was instructed that, on trials where a target was presented, it was twice as likely to appear in the same location as the cue than in the other location. Again we found that reaction times were significantly faster in validly cued trials than in trials where the cue provided misleading information about target location. There was no difference in his ability to discriminate target presence between conditions. He did not report awareness of a single target in the 640 trials where one was presented. We were, however, concerned that the results we had obtained might be interpreted not as evidence for behavioral consequences of spatial selective attention in the absence of awareness, but simply as an effect of energy summation between the cue and the target. In a further experiment we therefore reversed the relationship between cue and target location—if a cue appeared in one location it was now most likely that any target which followed would appear in the other location. We informed G.Y. of the change of conditions. We expected one of two outcomes to follow. G.Y. would either be incapable of using an indirect relationship between cue and target and would continue to respond faster in the minority of occasions when cue and target location coincided or he would be able to make use of his explicit knowledge of the new cue–target relation and would be faster when the cue was followed by a target in the other location as the rule specified. We found neither. For the first three blocks of testing (384 trials) G.Y. continued to show faster reactions when cue and target locations coincided. This is consistent with the schema he was using in the preceding experiment and is also what would be expected if the cues drove an automatic capture of visual attention at their location. Much to our surprise, however, as testing proceeded G.Y. became faster at responding to targets when they appeared in the location consistent with the attentional rule rather than appearing in the same location as the cue. Over the course of the whole experiment G.Y. was significantly quicker on validly cued trials and was also more accurate in discriminating target presence. In order to make this switch to an appropriate schema G.Y. need not have made use of his explicit knowledge of the spatial relationship between cues and targets—this relationship was also accessible implicitly through the statistical properties of the cue–target relationships with which he had been presented. G.Y.'s commentary responses indicate that he was not aware of a single target. During debriefings he also indicated that he was unaware of any of the cues. The substitution of an effective schema in replacement of one which had become ineffective as circumstances changed does not therefore appear to necessarily engage consciousness.

G.Y. demonstrates two modes of perception within his scotoma (Weiskrantz, Barbur, & Sahraie, 1995), one in which he reports no awareness of stimuli but is nevertheless capable of discriminating their properties in forced choice tasks and the other in which he reports awareness of stimuli, although he still denies having normal phenomenal visual experience of them. We examined whether this latter form of awareness had different effects on changing attentional conditions by using cues of such a high contrast that they elicited this ''nonvisual'' awareness. As one would expect, the high-contrast cues were very effective when cues and targets were most likely to be presented at the same location. When we again told G.Y. that we were switching to the indirect contingency between cue and target location we found that

G.Y.'s reaction times were speeded in the validly cued trials where the cue and target now appeared in different locations from the first block of testing. G.Y. summed up the difference between the experiments with low- and high-contrast cues: ''When I am aware [of the cue] I can try to attend to the other [i.e., valid] location . . . when I was not aware of any of the cues I could not try to switch my attention.''

Although we set out to test a series of hypotheses about the relationship between attention and awareness we have also unexpectedly discovered that metacognition, in the shape of a change of schema, need not give rise to awareness.

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