Aware Brains, Unaware Subjects

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COMMENTARY ON: LaBerge, D. (1997) "Attention, Awareness, and the Triangular Circuit". *Consciousness and Cognition,* *6*, 149-181. (See also LaBerge's precis for PSYCHE.)

1. Introduction

LaBerge gives a neurobiological account of awareness in relation to attention to objects, (motor) action, and attention to the action and the actor. LaBerge's arguments make use of the neuroanatomical fact of the existence of triangular neural circuits.

Such circuits may or may not be the basis of attention, of awareness, or any other subfunction of the brain. Of course, the frontal cortical system has to do with planned actions, the parietal cortex is involved in visuo-spatial attention, and subcortical structures mediate information to and from these cortical areas. This kind of direct or indirect connectivity can be seen as a triangular circuit within which something like awareness may happen. This commentary is concerned with the question of the experimental evidence that we have in favour of or against such a theoretical account.

We are looking for an experimental situation where the subject not only has to attend to and consciously perceive a sensory stimulus but is also required to attend to their own action or reaction in response to that stimulus, and to attend to their being the actor in this task. For this purpose one wants to look at a well studied sensory system, a closely related motor system, and attention as a mediator between the two. In addition, to make it comparable with LaBerge's argument, such a sensorimotor system should rely on frontal, parietal and subcortical functions.

We will consider the optomotor system as a possible candidate. Oculomotor actions, especially saccadic eye movements, are most intimately related to visual perception on the one hand and to visual attention on the other (Fischer & Weber, 1993). Saccades can be made reflexively or consciously and on purpose (Hallett, 1978). Voluntary saccades rely on an intact frontal system (Guitton, Buchtel & Douglas, 1985), whereas reflexive saccades can be generated by the occipital-tectal system (Schiller, Sandell & Maunsell, 1987).

Enhancement of visual neural responses specifically related to saccades has been described for neurones in several structures like the tectum (Mohn & Wurtz, 1976) and the frontal eye fields (Bushnell & Goldberg, 1979). Enhancement effects are also described in relation to visual attention in the parietal cortex (Robinson, Goldberg & Stanton, 1978) and in the prestriate cortex V4 (Fischer & Boch, 1981). For example, the activity of neurons in V4 can be modulated by the onset/offset of a central fixation point without the monkey making saccades and without any change of the visual conditions in the cell's receptive field (Fischer & Boch, 1985), indicating the effect of an inner brain process impinging on these cells.

With these facts one may expect that saccadic activity reaches consciousness given that the subjects are instructed accordingly. In everyday life saccades are made 3-5 times a second and they remain unconscious. One may therefore argue that the saccade system is not a good model to test LaBerge's theory. Yet the saccade system, in particular its voluntary components, forms a triangular circuit that fulfills LaBerge's criteria. In fact, normal saccades can be reported by the subjects if they are asked to do so. Therefore it seems interesting to see whether we can find conditions where the saccades remain unconscious despite the subject's intention to report them.

2. Experiment 1

The subject has to perceive a sensory stimulus consciously (enhancement and attention to an object), react to it by a motor action (control), and give an independent indication as to whether this action took place or not (attention to a representation of the self). To make sure it is a voluntary action (frontal control) we will dissociate the spatial direction of reflexive action from that of voluntary action.

The experiment to be considered is relatively simple: a subject is asked to fixate a small spot of light (the fixation point) straight ahead. The fixation point is switched off after a second and after another 200 ms (the gap period) another stimulus is presented to the right or left in random order. The subject is asked to generate a saccade in the direction opposite to that stimulus. This is the so called antisaccade task introduced many years ago (Hallett, 1978). The subject has to suppress the reflex to look at the stimulus, which is mediated by the tectum (Schiller et al., 1987). A sufficiently strong fixation system, a parietal function, can help. This, however, is not enough: a voluntary saccade must be made which requires an intact frontal cortex (Guitton et al., 1985). In this situation a number of observations can be made:

- First, even after extensive training, subjects cannot follow this instruction on every trial: They produce about 12% errors on average (Fischer & Weber, 1992). To help the subject to generate the correct antisaccades, the side to which the saccade has to be made can be indicated by a brief cue stimulus 100 ms before the go stimulus on each trial. This manipulation should provide an extra activation of the attentional system (a parietal function) and help the subject to prevent these errors.
- Surprisingly, instead of decreasing their error rate and reaction times, subjects produced even more errors (30% on average) and the correct responses had longer reaction times (Fischer & Weber, 1996). Therefore, to encourage subjects to attend to their actions (and to provide a measure of awareness of errors), they were asked to press a key at the end of each trial to indicate whether they believed that they made an error.
- These subjects already knew about the general findings and they tried to avoid not only the generation of the errors but also tried to observe themselves during the trials. However, they produced many errors and were unaware of about 50% of them. Yet, 98% of these errors were corrected (Mokler & Fischer, 1998). Corrections occurred when the subject, after having made the first saccade to the stimulus (the error), produced a second saccade to the originally required opposite side (the correction). These findings reveal a striking mismatch between what the subjects really did and what they believed they did.

3. Experiment 2

In a second experiment the subjects had to detect the last orientation of a small stimulus, when its orientation was changing at a rate of about 6 per second between up, down, right, or left. The fast changing stimulus was presented for a randomly varying period of time before it disappeared. Only then had the subjects to press a key corresponding to this last orientation. An experimental block consisted of at least 50 trials. After the experiment the subjects were asked whether they believed they performed this task correctly, giving an estimate of the number of trials where they correctly guessed the orientation.

The result was that many subjects underestimated their performance by far. They complained that they could not see the orientation because of its high rate of change, yet they performed well above chance level (personal unpublished observation). Again we have a case where subjects attended to themselves doing the task, paid attention to the stimulus - trial by trial - yet were unaware of the accuracy of their performance.

4. Clinical Cases

Patients with lesions in one or the other structure of a triangular circuit may be considered as another kind of "experiment". Again we have a chance to look specifically at eye movement behaviour because the tectal, the parietal, and the frontal systems are members of a triangular circuit (as pointed out by LaBerge's Fig. 4 [Fig. 3 in the precis]) and all three structures are involved in directing the fovea from one place to the next.

In case of frontal lesions the subjects are impaired on the antisaccade task and so are patients with parietal lesions. The former patients are believed to have lost their voluntary control over the movement of their eyes, whereas the latter may have lost their fixation control and therefore cannot prevent their tectal reflexes from pulling the eyes to the stimulus. One way of differentiating these cases is to look at the corrective saccades following the errors: if the errors remain largely uncorrected or corrections are associated with long reaction times this may indeed indicate a relative loss of voluntary control. If on the other hand, the errors are mostly express saccades with rather short reaction times and if these are almost all corrected after short correction times, it may be argued that this indicates a relative loss of fixation control (Biscaldi, Fischer & Stuhr, 1996). In both cases one wants to know whether the subjects are aware of the errors--which is at the moment is an open question.

Since many of the clinical cases are unilateral lesions, the question of the bilateral organization of awareness arises. Of course, these patients are impaired only for one side. Also, there are always a few normal subjects who are impaired on the antisaccade task to one side but not to the other. Of course, the triangular circuits exist in both hemispheres and one wonders whether these subjects are asymmetrical with respect to their awareness.

5. Development

Finally, I want to mention the developmental aspect of the problem of awareness. When looking at children at the age of 10 years they are still almost unable to perform the antisaccade task in a gap condition. Their error rate is 60% on average with a large scatter from one child to the next. The voluntary saccade component develops until age 15-18 years. Yet, their fixation system and the reflexive saccade generation are already well developed and undergo only little change until adulthood (Fischer, Biscaldi & Gezeck, 1997). One wonders whether the degree of awareness follows these trends. Given that the elements of triangular circuits in both hemispheres develop during different periods of life, the degree of awareness should follow the development of the latest component. This is another open question, which could be answered experimentally.

In all of these cases we need a definition of awareness which allows a quantitative measurement of the degree of awareness or of the number of awareness events. The above mentioned experiments and the clinical cases represent only a few possibilities.

6. Summary

LaBerge's article deals with the problem of awareness from a cognitive point of view while trying to relate it to anatomical structures and connections. The present contribution points to possibilities of approaching the problem from an experimental point of view. Observations mentioned above should be taken into account by any concept of awareness. Despite the presence of the anatomically defined triangular circuit (e. g. frontal - parietal - tectal), despite the response enhancement taking place trial by trial (at a subcortical and/or cortical level), despite the subjects' decision to generate a voluntary saccade on every trial (frontal), and despite the subject attending to themselves as an actor throughout the duration of the experiment, a considerable proportion of the errors and their corrections escape the subjects' conscious perception. From all we know we have to assume that the triangular circuits are activated under these circumstances yet awareness does not always take place. Are these cases where the subjects' brains are aware, but the subjects are not?

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