The Conundrum of Unconventional Consciousness:
Comments on LaBerge's Theory of Attention and Awareness

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

1. Introduction

LaBerge's (1997) theory of attention and awareness presupposes a highly compartmentalized brain in which discrete areas perform distinct mental functions. Objects are represented in the sensory cortices. Habits and interests are in the basal ganglia. Control of attention is carried out in the prefrontal cortex. The self is represented in the frontal lobes. Bodily landscape and verbal information are contained in the self-representation area, which is organized in columns like other cortical areas.

A theory's value can be estimated according to a number of different criteria. The chief factors considered in this review are internal consistency, agreement with empirical evidence, and fruitfulness in fostering the accrual of additional scientific knowledge. Evaluating a theory of mental activity presents special difficulties. Multiple word meanings promote misconceptions. Equivocation can cloak fallacious reasoning. The "facts" are often controversial, because they are inferences based on long chains of reasoning. Tacit assumptions are more numerous, but not less important, than the ones explicitly stated. The recency of LaBerge's theory is a difficulty for estimating its fruitfulness. When the vantage of a later point in history has arrived, it may still be hard to judge, since debate continues today on the impact of other theories of mental function that were offered a century a more ago.

2. Definition of Terms and Internal Consistency

The most surprising aspect of LaBerge's theory is the proposal that awareness requires the direction of attention to a representation of the self. Applying this rule to an example that he provided in his paper yields a startling conclusion. A person strongly attending to a bird struggling against a window, but not paying attention to his or her own action of attending to that event, would not be aware of what was happening. The conundrum of strong attention coupled to absent awareness arises because attention and awareness in LaBerge's theory have meanings that differ from those used in common parlance.

Awareness of an event is ordinarily demonstrated by showing that a person has detailed knowledge of it. Suppose the bird-attentive, non-self-attentive person could correctly answer whether the bird had beaten its wings or pecked on the pane and could make accurate judgments on its color and size. If such knowledge did not count as awareness of the event, because personal involvement was absent, then awareness as LaBerge defines it must be something that transcends the mere knowledge of details. It might be a sense of exhilaration or a heightened form of consciousness generated by personal participation in the event. The transcendent meaning of awareness would allow a person to truthfully testify that he or she was not aware of an event, despite proof that he or she had detailed knowledge of it. It is doubtful, however, that a jury would accept absence of attention to the self-representation as an exculpatory excuse.

It was not clear from LaBerge's account that the bird-attentive, non-self-attentive person did know details of the bird's struggle. If he or she did not, the meaning of attention becomes an issue. An inability to supply relevant information is ordinarily regarded as evidence of inattention. A student unable to refute the charge of not paying attention by correctly answering his or her teacher's queries might claim that he or she really had been attending strongly to what was being taught, but did not know what it was, because he or she had not been paying attention to his or her self-representation. This is unlikely to satisfy the teacher, who wants the kind of attention that leads to knowledge. Thus, absence of attention to the self-representation could be used as an excuse for knowing the details of an event but not being aware of them, in the case of the witness, or for not knowing the details despite paying strong attention, in the case of the student.

The paradox is resolved when it is understood that in LaBerge's theory attention is not a mental activity. It is instead a stream of action potentials emanating from the prefrontal cortex. If directed only to the sensory cortex and not to the representation of the self in the prefrontal cortex, awareness doesn't occur, by definition. That is, the person wasn't really strongly attending to the bird as ordinarily understood. He or she was only transmitting streams of action potentials from prefrontal cortex to sensory cortical areas without simultaneously sending other action potentials to the self-representation in the frontal cortex.

3. Conflict With Brain Pathology Consequences

Placing the control of attention in the prefrontal cortex presents some obvious difficulties. Pertinent information comes from tests of frontal lobectomy patients (Stuss & Benson, 1983). Signs of damage to the prefrontal cortex included personality changes, linguistic deficits, impaired response inhibition, specific disorders affecting memory, and motor problems. However, little or no deficit was found on standard tests of intelligence and frontal lobe lesions had less effect on IQ than pathology in posterior cortical areas. Dorsolateral patients did not appear to have attentional deficits and patients with very large orbital lesions did not differ significantly from normals on tests of attention, sustained mental activity, and mental flexibility. The authors thought that lesions in these locations do not result in impaired attention, although they conceded that their conclusion depended on how attention is defined. Frontal lobe lesions might lead to deficiencies only in "higher order" attention, such as the selection of strategies of response.

Recognizing the problem that frontal lobe damage presents for the idea that the prefrontal area normally functions to control attention, LaBerge argues that tests may have been insensitive to the more challenging aspects of attention and that another area could carry out some operations of attentional control if the frontal area was not available. Thus, the attentional control exerted by the prefrontal area refers only to certain specialized forms of attention, not attention in the broader sense of the term. The permanent blindness that results from damage to visual cortex in humans justifies the claim that it is crucial for vision. By contrast, the idea that an optional site exists for the control of attention clashes with the claim that the prefrontal cortex is "crucial for attentional control." Another problem arises if the attentional control function of the prefrontal cortex is transferred to some other area of the brain. How could attention be directed to the self-representation, which is presumed to be located in the frontal cortex? If it did not have an optional site too, a frontal lobotomy patient would never have any awareness.

4. Problems For Interpreting Brain Blood Flow Experiments

Much of the evidence LaBerge cites in support of the prefrontal area being the controller of attention comes from studies of regional cerebral blood flow (rCBF). Computing the difference in the blood flow images taken when a person performs two different tasks provides a deceptively simple approach to locating processing centers in the brain. Suppose a blood flow map was constructed from data obtained while a person attended strongly to a bird but not to his or her self-representation and another map was constructed when he or she attended to both the bird and his or her self-representation.

According to the logic of the brain-imaging paradigm, the area where there was a large difference in blood flow for the two tasks should indicate where the self-representation was in the brain. This would occur because the excitation of the self-representation area would increase metabolism there, producing a greater demand for blood. LaBerge is clear in specifying that the prefrontal cortex must excite both the cortical area representing the object and the cortical area representing the self for awareness to occur. It is less clear whether awareness is only a hypothetical construct or a function that can be localized to a particular area of the brain. A problem arises if awareness is localizable. The difference map would show increased blood flow in both the self-representation area and the awareness area. To distinguish them from one another, the person could be instructed to attend only to his or her self-representation and pay no attention to the bird. Excitation of the self-representation area should continue, but now there would be no awareness and no increased blood flow in the awareness area, because the person was not attending to the bird.

LaBerge identified one of the problems for the experimental approach described above. It is difficult to know whether a self-attended event has occurred or not. That admission weakens the claim that the theory is testable. Similarly, it is difficult to know whether an object-attended event has occurred, if it is possible for a person to strongly attend to a bird's struggle without being able to supply details of the event.

5. Increased Blood Flow May Not Correctly Identify the Site of Processing

Suppose a female being observed by male experimenters read neutral stories in one condition and lewd tales in another. At first blush an observed difference in the two blood flow maps might seem to represent an area whose function was the processing of erotic images. On learning that the two patterns of blood flow had been derived from the skin overlying the face and chest, the need for reinterpretation would be obvious. It seems self evident that the skin could not be responsible for the processing of the erotic material. If the difference map had been obtained from the flow of blood in the brain, the possibility that an erotic processing area had been identified would be improved. However, supposing that every local increase of blood flow in the brain implies that a greater amount of processing is going on there requires a leap of faith. Numerous assumptions must be made. Homogeneous distribution of energy reserves is one of them.

6. Homogeneity of Sensitivity to Changes in Energy Consumption

The brain can get glucose for energy from the breakdown of glycogen contained in astrocytes as well as from the blood (Roland, 1993). Some brain areas may be endowed with greater blood circulatory resources than others. Faced with an increase in metabolic demand, the adjustment in blood flow needed for an area well endowed with reserve energy or circulatory resources might be less than for an area that ordinarily receives barely enough blood to meet metabolic demands. If performance of a task produced greater metabolic activity throughout the brain, the observation of a local difference in blood flow would not identify where greater processing had occurred, but rather a part of the brain that was more sensitive to fluctuation in metabolic demand. A brain area that was volatile in adjusting blood flow would be expected to show up on blood flow difference maps for a variety of tasks that consumed energy resources in widespread brain areas. Frackowiak (1994) found it remarkable that so many seemingly different tasks activate identical areas of the brain. Roland (1993) provided a list of tasks activating fields in the superolateral prefrontal cortex. Considering their wide variety, he wondered if there were any tasks that were not associated with activations in that area. Non-homogeneous sensitivity to changes in energy consumption might be one of the reasons.

7. The Relationship of Energy Consumption to the Amount of Processing

The assumption that the amount of processing performed is proportional to the amount of energy consumed can also be questioned. Generating a beep to indicate the completion of a computer operation might consume more energy than a highly sophisticated analytic subroutine. In the brain, procedures that increase action potential frequency and excitatory postsynaptic potentials in the cortex are thought to increase the energy consumed, thereby increasing local blood flow. The energy consumption resulting from inhibitory postsynaptic potentials is more problematic. Some energy would be consumed by the synthesis and release of inhibitory transmitter substances, but the effect of the inhibition on postsynaptic cells might decrease energy consumption. LaBerge concluded that distant fibers projecting on cortical columns have an overall excitatory effect, because 80% of cortical neurons are excitatory and 85% of the synapses in the cortex are excitatory. An implicit assumption is that excitation and inhibition at a synapse have equal and opposite effects. If the potentials generated at inhibitory synapses have longer duration than those at excitatory synapses or if the inhibitory synapses are located closer to the action potential generating zone of the post synaptic cell, the assumption is violated. Ignoring these factors suggests an inordinate preponderance of excitation. It is doubtful whether the proposed imbalance occurs in normal states of the brain. A neuron would receive an ever greater amount of excitation, pass it on to other neurons, and ultimately produce maximal firing of action potentials in them, if the spread of excitation was not limited by some means. It seems likely that excitation and inhibition both have a role in the processing of information and questionable that a preponderance of excitation implies a greater amount of processing, even if it did consume more energy.

8. Psychological Assumptions

The blood flow difference approach also requires assumptions in the psychological realm. It is open to the same criticism that was directed at the subtraction method that F. C. Donders (1868/1969) used to measure mental processes. Donders reasoned that the time required for a mental process could be determined by subtracting reaction time in a simple task from that for a more complex task. The difference would indicate how much time was used up by the added element of complexity. Kulpe argued in 1893 that the method was invalid, because total processes are not just compounds of elemental separate parts (Boring, 1952). Changing the task altered the whole process rather than just adding an additional part. The Kulpe fallacy is relevant to the subtraction procedure used in studies of cerebral blood flow, because an added task element typically increases task difficulty. Manipulating the degree of mental effort required by a task affects many physiological measures. Some examples are cardiovascular activity, pupillary dilation, facial expression, neck and shoulder muscle tension, blink frequency, eye movements, and electrogastrographic activity. The mere prospect of having to solve easy or hard problem has physiological effects. Cohen and Waters (1985) found differences in heart rate, skin conductance, and skin temperature during cue phases, when a subject was informed of the semantic difficulty of an upcoming word task but was not yet performing it. Subjects told to expect difficult math problems showed greater changes in cardiovascular activity than those told to expect easy ones (Contrada, Wright & Glass, 1984). These results suggest that differences in cerebral blood flow might reflect emotional responses related to task difficulty, rather than just the addition of a different type of processing in the brain.

Neafsey (1990) and Buchanan and Powell (1993) reviewed prefrontal cortical control of the autonomic system. Most portions of the prefrontal cortex represent the viscera or eye-head movement. Electrical stimulation of prefrontal cortex in animals produces changes in blood pressure, heart rate, and salivation. Rhesus monkeys with bilateral lesions of the dorsolateral frontal cortex did not show GSR changes to pure tones or light flashes, unlike controls (Grueninger, W.E., Kimble, Grueninger, J. & Levine, 1965). In ten-month-old human infants, happy facial expressions produced greater activation of left frontal EEG than sad expressions (Davidson & Fox, 1982). In adults with focal lesions, the dorsolateral prefrontal region was one of the areas in the frontal lobe that was implicated in defective skin conduction responses to affectively laden pictures (Tranel & Damasio, 1994). These findings suggest that arousal and emotional responses evoked by stimuli or task demands would be associated with altered rCBF in prefrontal areas. Evidence that cerebral blood flow could change with emotional state was provided by J.V. Pardo, P.J. Pardo and Raichle (1993). Male subjects recollecting situations that made them feel sad showed left orbitofrontal and inferior frontal increases in blood flow. It is uncertain that changes in emotion caused the change in blood flow pattern, because other changes may have occurred at the same time, such as the retrieval of events from memory, mental imagery, and inner speech. The point of mentioning these confounded factors is not to argue that changes in emotion do not alter brain blood flow. The point is more general. What is called into question is the assumption that changing one element of a task changes only one process in the brain. It seems more likely that alteration in a task instead changes a whole spectrum of activities.

9. Too Many Mental Functions--Too Few Brain Areas

It might be argued that although a wide variety of tasks activate the prefrontal cortex, the areas activated are not identical. The functions of the prefrontal area might be parceled into small enough patches to accommodate them all. Maps showing activation of relatively small areas have been reported, but they may underestimate the amount of brain tissue that is involved. Steinmetz and Seitz (1991) thought they were artifacts of inter-subject averaging. The implicated areas actually represented the overlap of more extensive regions that were variably located in different subjects. The size of an implicated area depends on the significance threshold used in plotting the difference map. Lowering it caused separate areas at the base of the frontal lobe to increase and coalesce into a single region (Andreasen, 1996).

A task requiring subjects to think up usages of words activated the left dorsolateral prefrontal cortex, so it was identified as a semantic processing center (Petersen et al., 1988). There was no activation in Wernicke's area. The absence of activation conflicted with evidence suggesting a central role for Wernicke's area in word comprehension and retrieval (Wise et al., 1991). Should the absence of a significant change in brain blood flow in a given area be taken as evidence that it was not involved in performance of a task? Perhaps it should not. The absence of a blood flow change in an area might mean that processing was so efficient there that it was accomplished almost effortlessly. The area might be specialized for a particular type of processing and its computational results might not be directly funneled into a narrow behavioral output channel. In the Petersen et al. (1988, 1989) studies, simple movements of the mouth and tongue activated the same area in left prefrontal cortex that was activated by the word use generation task. It has been suggested that activation there may reflect "inner speech" (Gur et al., 1988; Demonet, Price, Wise & Frackowiak 1994; Price et al., 1994). This is consistent with the classical association of Broca's area with language production as opposed to language comprehension. Close connection with output to the body could provide a reason for concentrated neural activity. Recording EMG from speech musculature, Sokolov (1972) found that phasic impulses suggesting inner speech increased with task difficulty until the task became very hard, when it was reduced again. Neither the Petersen et al. (1988, 1989) idea that the left dorsolateral prefrontal cortex is a semantic processing center nor the idea that it is involved in the generation of inner speech are easy to reconcile with the functions LaBerge assigned to this brain area. In his view, circuits serving visual attention for location originate in the dorsolateral prefrontal cortex, in contrast to those serving attention for shape, which originate in the ventrolateral prefrontal cortex.

Opinion on the importance of confounded variables in interpreting blood flow maps varies. Some investigators have argued that differences in task difficulty (Shaywitz et al., 1995) or subject strategy (Posner, Petersen, Fox & Raichle, 1988) were absent. The reasons adduced seem less than compelling when closely scrutinized. Petersen et al. (1989) conceded that arousal might be a confounded factor, but preferred to discuss more intriguing possibilities. Others (e.g., Grasby et al., 1994; Kosslyn et al., 1994) took a more serious view, cautioning that the theoretical assumptions implicit in the subtraction paradigm pose an important problem. Wise et al. (1991) suspected that the intermingling of the networks involved in attention, memory, and semantic processing made it unrealistic to expect to find unique anatomical areas for each system. The large impact of small variations in experimental design led Price et al. (1994) to conclude that association of the left frontal cortex with specific psychological processes was premature. Thus, strength of faith in the ability of blood flow difference maps to identify specific mental functions varies considerably among investigators.

10. Historical Perspective

A nineteenth century text by the Fowler brothers (1859) shows a picture of Aaron Burr with a large bump at the back of his head. He had a reputation as a womanizer and the back of the head was the amativeness center. The satiric novelist Lawrence Sterne is pictured with a head bulging in the prefrontal area. Persons large in this area, it was claimed, "delight to make fun out of everything not exactly proper or in good taste." Nowadays few take these relationships seriously. Little attention is paid to phrenology and its map of function in the brain. It is a sobering thought that a theory of brain function flourished for a full century in spite of ill accord with facts. Although manifestly a failure from a factual standpoint, the fruitfulness of phrenology is more difficult to evaluate. It helped to solidify belief in the brain as the organ of the mind and it suggested that different parts of the brain would have different physiological and possibly psychophysiological functions. On the other hand, it also contributed to the idea that each area of the brain has a single function which, once determined, precludes it from having other functions and denies other areas that function as well. The flexibility of function in brain remains a contentious issue. Where connection to the body is close, it seems that the function of lost brain tissue can be established--as in cortical blindness or deafness. The case for strict localization of more purely mental functions, such as attention, memory, and awareness, is much less well established. Use of the Internet may serve as an analogy. If the cable or phone line connection to the network is cut just outside one's house, communication is disrupted. If one or more remote nodes become inoperable, the consequences are less severe, because connections previously using them can be reestablished via alternate routes.

The denouement of the long continuing controversy between proponents of strict localization of function and their equipotential adversaries does not seem imminent. The blood flow method of identifying processing centers, as currently practiced, seems incapable of providing definitive answers. Advances in technology and psychological testing procedures might alter the situation. History will decide whether scientific opinion tilts more toward strict localization of function or equipotentiality. Even if details of LaBerge's theory should prove to be incorrect, it could be said to have had a measure of success if opinion shifts toward strict localization, because his model of attention and awareness demanded a highly compartmentalized brain in which discrete brain areas performed distinct mental functions.

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