# Five Enigmas Regarding LaBerge's (1997) Triangular-Circuit Theory of Attention and Self-Referential Theory of Awareness

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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.)

## Introduction

I believe that, on balance, LaBerge (1997) has produced a strikingly clear and data-based theory or vision of how selective attention could be produced in the human brain. There would be little point in criticizing it for being somewhat speculative, inasmuch as it seemed to be offered as a set of hypotheses that could serve to organize what is known about the cognition and neuroscience of attention and to motivate further research in these areas. However, there are some past findings that may not fit well within this general vision. I will focus on what I perceive as 5 enigmas stemming from apparent discrepancies between LaBerge's theory and past evidence. This focus may lead eventually to a better resolution in which the apparently discrepant findings are taken into account, either through a modification of the theory or through a further elaboration of its

principles. The enigmas are presented below in the order in which they occurred to me while reading the target article.

# 1. The Enigma of Parietal Lobe Damage and Hemispatial Neglect

LaBerge suggested a mechanism of attention involving (a) diverse cortical areas as the expression of attention, (b) the prefrontal cortex as a controller of attention, and (c) thalamic areas as modifiers or energizers of attention. Given that view, it is not clear to me how the phenomenon of hemispatial neglect would be accounted for. This phenomenon occurs most frequently with damage to the right parietal lobe and involves a failure to attend to information in the left half of space, or even in the left half of a mental image, despite the preserved ability to perceive objects in that half of space (e.g., Bisiach, 1992; Heilman, Watson, & Valenstein, 1985).

There are also other, related defects of awareness that seem to result most often from right parietal damage, such as a syndrome in which a hemispatial neglect patient denies ownership of his or her limbs on the left side of the body, and anosognosia (the inability to be aware of a serious physical problem such as left-sided paralysis). These deficits can result also from frontal damage but are apparently non-existent or rare when the damage is confined to the occipital or temporal lobes. These types of phenomena led Schacter (1989) to suggest that the parietal lobes play a special role within awareness or consciousness. Cowan (1995) summarized additional, subsequent evidence supporting that basic view, including neuroimaging and neuropsychological studies showing that attentional orienting heavily involves the parietal areas (e.g., Posner & Peterson, 1990; Posner, Walker, Friedrich, & Rafal, 1984).

The problem is that the parietal lobes hold no special place in LaBerge's theory. Parietal damage could result in a deficit in awareness according to his theory, but it is not clear why it would do so in a more fundamental way than temporal or occipital damage. So, either the triangular circuit theory is incomplete or the past evidence for special parietal involvement in attentional orienting has been somehow misinterpreted.

# 2. The Enigma of Cognitive Inhibition

LaBerge described neurophysiological evidence that long-distance connections between nerve cells are overwhelmingly excitatory rather than inhibitory in nature and that inhibitory connections are local rather than long-distance in nature. He stated (p. 156) that "voluntary influences on the expression of attention arrive by means of excitatory fibers over long-distance connections." Specifically, it was suggested that the control of attention occurs through enhancements of neural firing from the prefrontal areas and the

thalamus, which have different effects but are excitatory in both cases. It was suggested that the cellular column is the basic unit that may represent a concept, and that inhibition would occur, at most, as a local suppression of one unit by another. Thus, LaBerge stated (p. 158) that "retina-driven signals in the target columns, under the regulatory influences of top-down signals, subsequently inhibit the activities in neighboring distractor columns, or else these activities simply decay."

Notice, however, that this view seems to include only a certain kind of inhibition. If Column A is enhanced via attention it may spread inhibition across all neighboring columns (B, C, D, etc). This type of inhibition is not specific. In contrast, many types of apparent inhibition observed in the cognitive literature do seem specific (e.g., inhibition only of Concept B with no effect on Concepts A, C, or D). It is not clear how to reconcile these results.

One example of inhibition is negative priming (e.g., Tipper, MacQueen, & Brehaut, 1988). In a negative priming procedure, a to-be-attended and a to-be-ignored stimulus are presented at the same time in close proximity. For example, the subject may be told to respond to green stimuli and ignore red ones, or to respond to pictures but ignore words. Then the irrelevant item on Trial n-1 becomes the relevant item on Trial n. In a Stroop color-naming task with negative priming, the subject might get the word "red" in blue ink (the correct response being "blue") and then the word "green" in red ink (the correct response now being "red", which was the distractor on the previous trial). It is found that responding to a target item on Trial n is slower when that item was also the distractor on Trial n-1 than when it was not. This "negative priming effect" appears to result at least partly from attentional inhibition, given that it is not obtained if the subject is a young child who may not be neurally mature enough to exert such inhibition (Tipper, Bourque, Anderson, & Brehaut, 1989) or if a supplementary memory load is imposed during the negative priming procedure (Engle, Conway, Tuholski, & Shisler, 1995). The assumption is that inhibition is exerted during Trial n-1 in order to prevent incorrect responding to the distractor and that it has not yet dissipated by Trial n.

Inhibition serves to reduce the possibility of an incorrect, yet tempting, response. Gernsbacher (1993) reviewed evidence from various studies in which there was a reaction time cost of receiving a potentially ambiguous stimulus (e.g., a printed word like "spade" that has two meanings, or a spoken homophone that can be interpreted as either "patients" or "patience") as compared to an unambiguous stimulus, in the presence of a sentence context that was capable of resolving the ambiguity (e.g., "He dug with the spade"). The studies uniformly showed that less-skilled readers were less able to suppress the incorrect interpretation of the text and therefore suffered a greater reaction time cost of receiving ambiguous stimuli. In another kind of experiment, less-skilled readers were unable to suppress a word printed on top of a picture (e.g., the word "rain" printed on top of a hand) in order to determine if the picture (not the word) was related to a second picture (e.g., an umbrella; the correct answer here is "no"; it is not related to the hand).

Additionally, inhibition has been linked to the functioning of the prefrontal cortex (for reviews see Cowan, 1995; chapters in Richardson, Engle, Hasher, Logie, Stoltzfus, &

Zacks, 1996). For example, object permanence errors in infancy occur in an "A not B" situation. In this situation a toy is first hidden in container A and the infant (who must be mature enough) manages to retrieve it. Then the toy is hidden in Container B, but the infant continues to look for it under Container A (the "A not B error"). Although Jean Piaget thought this resulted purely from the loss of memory for the object, subsequent demonstrations showed that this is only part of the story. For example, A not B errors continue even when the containers are transparent so that the toy remains in sight. It has been theorized that part of the A not B error occurs because the infant is unable to use the most recent memory representation to inhibit what has become a prepotent or reflexive response (Diamond, 1985; Diamond & Gilbert, 1989). This error is elicited also in adult monkeys who have received prefrontal ablations (Diamond, 1990). It is difficult to see how this type of effect can be reconciled with the purely excitatory direct action of the prefrontal cortex that LaBerge described.

# 3. The Enigma of Distractions

Compared to Cowan (1995), LaBerge assigned a much smaller role to the effect of changes in the environment in driving shifts of attention. He reasoned that events that interrupt voluntary attention do so only infrequently and momentarily, and he suggested (pp. 164-165) that "columns of attentional expression can almost always reach higher levels of activation when they are controlled by top-down sources than when they are driven by bottom-up sources."

The main reason that I disagree with this statement is that I view bottom-up and top-down information as influencing attention together. Although abrupt shifts of attention may not occur most of the time, bottom-up information from the environment will make it easier or more difficult to exert voluntary control of attention on a more continuous basis. For example, a lecturer with a monotonic voice is difficult to listen to, whereas a lecturer with exciting changes in tone of voice tends to be much easier to listen to. Cowan (1995) would assume that orienting responses to changes in tone of voice make it easier to attend to the speech because orienting and voluntary control of attention are working together. At the other extreme, if the speaker is monotonic and is speaking during a thunderstorm, orienting responses to the thunder may make it quite difficult to pay attention. Thus, I believe that orienting responses to bottom-up information should receive a more prominent role in any realistic theory of attention.

# 4. The Enigma of Perception Versus Imagination

LaBerge speculated (p. 170) that the neural influence of the prefrontal areas on diverse cortical areas may lower the threshold for seeing a particular object but cannot substitute

for the object itself; the neural effects of bottom-up and top-down information on cellular columns differs, so that perception and imagery are not confused with one another.

To a certain extent I agree. Keller, Cowan, and Saults (1995) showed that there is a stark difference between perception and imagery in the auditory modality. Subjects had to compare two tones, separated by a 10-second silent period, that sometimes differed slightly in pitch. No noise was placed in the inter-tone intervals, but the silent task differed. It turned out not matter at all whether subjects silently rehearsed a new melody or a new sequence of digits during the intertone interval; there was no specific interference with auditory sensory memory from musical imagery as opposed to speech imagery. Performance in both of these imagery conditions was somewhat poorer than in a no-interference control condition, suggesting that auditory memory can be prolonged with some sort of rehearsal.

There have been suggestions of interactions between imagery and perception in other circumstances. Perky (1910) projected very dim, colored images on a screen and asked subjects to imagine various objects; they were found to incorporate the color of the projection into their images more often than chance would dictate, even though they were unaware of any projection on the screen. However, in this phenomenon a percept is mistaken for a mental image. That state of affairs does not really contradict LaBerge's theory because it may just mean that an incorrect inference was made about the very weak, subliminal stimulus.

It would seem more damaging to the theory if mental images were incorrectly interpreted as percepts. Evidence regarding this comes from Farah (1985, 1989). In the task used by Farah (1985), subjects attempted to detect a faint letter while imagining another letter. If they were imagining a letter that matched the stimulus in both identity and location, imagery facilitated the task. If the imagined and projected letters differed in location, identity, or both, letter detection was impeded. However, Farah (1989) analyzed related evidence according to signal detection theory and found that imagery caused only shifts in criterion, not changes in signal sensitivity. She concluded that "imagery is an attentional state," which seems in accord with LaBerge. (For further debate of this important issue of the relation between perception and imagery see Behrmann, Moscovitch, & Winocur, 1994; Goldenberg, 1995; Heil, Rosler, & Hennighausen, 1993; Ishai & Sagi, 1995; Miyashita, 1995).

Certain other uses of top-down information may not be as easily accounted for, however. For example, top down information seems to be mistaken for bottom-up information in the phonemic restoration effect (Warren, 1970), in which a phoneme within a word is replaced by a noise segment such as a cough, but the word is still heard as complete behind the noise segment even though the only bottom-up information is the non-speech noise.

Thus, it is still unclear exactly what behavior the neural model must account for. It seems that the model should predict that subjects usually, but not always, can tell the difference between sensory information and top-down expectations.

# 5. The Enigma of Awareness and Self-Awareness

In the last section, LaBerge allowed himself a bold leap. He defined "consciousness" as being the same as awareness only when the latter includes an element of self-awareness (e.g., the thought behind "I am trying to catch the bus" would qualify; "the bus is leaving" would not). Not all awareness is consciousness by this definition. The definition was justified by LaBerge partly on the grounds that self-awareness provides a context within which the attended percept can be placed.

This step does not appear to be onto truly new ground. Tulving (1985) made a distinction between "noetic" consciousness and "autonoetic" consciousness that appears to correspond well to LaBerge's distinction between awareness without, versus with, self-awareness. Tulving related noetic consciousness to semantic memory and autonoetic consciousness to episodic memory.

An important goal, however, is to establish an objective criterion for consciousness. If it is to be more than an epiphenomenon, it must have some role in processing, such as allowing more flexible responding (Shiffrin, 1986) or allowing a stable memory trace to be formed (Tulving, 1985). It is not clear if "self-awareness" per se meets either of these two particular criteria (although there probably are other important criteria that I will not consider here).

Self-awareness may or may not allow flexibility in performance. It may allow one to respond in a way that makes the most sense given one's personal goals, but it also can interfere with performance (as when one "chokes" in a high-pressure test situation; for a literary dramatization, consider the statement made by the main character of Notes from Underground by Doestoevsky, to the effect that self-awareness is a disease).

Self-awareness does assist memory, but perhaps not in a way that lends it a unique status. A dramatic example of this is the "self-reference effect" (for a review see Symons & Johnson, 1997). This effect is an extension of the research done earlier from a levels-of-processing viewpoint. Craik and Tulving (1975) found that people remember printed words more successfully if they carried out a relatively deep processing task on the item (e.g., a semantic judgment) rather than a shallower task (e.g., a phonological judgment or, even shallower, an orthographic judgment). In the self-reference effect it is found that the best recall of all occurs when the subject is asked to relate the item to him- or herself (e.g., "does this word name an object that you own?"). However, nearly as high a level of recall is obtained when the task involves other-person reference (e.g., "does this word name an object that your mother owns?") rather than self-reference. Symons and Johnson concluded that the self-reference effect occurs mainly because the self is an extensive, systematic schema that helps subjects to organize and classify the stimuli, and that other elaborate schema are similarly useful. If this is the case, there may be no unique status of self-awareness within any definition of consciousness that meets the memory criterion. It may be contextual information in general that serves the desired role.

# 6. Summary

LaBerge's article certainly is interesting food for thought. I have pointed to five topics on which more work may be needed before the theoretical view will be adequate: (1) the role of the parietal lobes and defects in awareness associated with them, not explicitly represented in the theory; (2) the mechanism of behavioral inhibition; (3) the extent of the role of bottom-up information in recruiting attention automatically; (4) the basis of occasional, apparent confusions between bottom-up and top-down information; and (5) the role of self-awareness and criteria for a scientifically useful definition of consciousness. There may well be answers to some of the questions I have raised within the triangular-circuit theory. If so, I hope that the present considerations will at least lead to a more complete articulation of the theory.

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