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Consciousness and Cognition 11 (2002) 475–477

Consciousness and Cognition

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Commentary

Where conscious sensation takes place

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Received 15 February 2002

Abstract

Pockett (2002) has drawn an alternative conclusion from the data of Libet, Alberts, Wright, and Feinstein (1967), and suggested that it takes 80 ms, rather than 500 ms, for the sensation evoked by a stimulus to enter awareness. Here, I suggest that our conscious sensation evolves over time, during the period from 80 to 500 ms after a stimulus, until the sensation is stably localized in space.

Pockett (2002) has hypothesized that it takes 80 ms for the sensation evoked by a stimulus to enter awareness. This hypothesis is drawn from data reported by Libet et al. (1967), who showed that the primary positive evoked potential elicited by a stimulus to the skin or to the ventral posterolateral nucleus of the thalamus is not sufficient for sensation. A suprathreshold single stimulus that elicits conscious sensation is accompanied by larger negative components that succeed the primary positive potential, and in addition by still-later positive and negative waves that are smaller and longer lasting. Pockett (2002) pointed out that the peak latency of the negative component that becomes evident when the sensation threshold is reached is in the range of 80–100 ms. In contrast, the later and smaller components last longer, up to ~500 ms. If we hypothesize, as Pockett (2002) did, that *simple conscious sensation* is represented by the earliest of the many evoked potential components that

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PII: S1053-8100(02)00031-4

appear only when the stimulus reaches the sensation threshold, then the latency for conscious sensation should be in the range of 80–100 ms. However, it is still possible that later components are essential for conscious sensation. It is only with further evidence that we can exclude any component, be it the earliest (70 ms) or the latest (500 ms), from being responsible for our conscious sensation.

In any case, there is a consensus between Pockett (2002) and Libet et al. (1967), in that the initial neural activity in the somatosensory cortex, as represented by the primary positive evoked potential, is not sufficient for conscious experience. That is, some neuronal activities other than the initial activity in the primary sensory cortex are required to elicit conscious sensation. I am most curious about the nature of these later activities that are hypothesized to be indispensable for our conscious sensation.

I suggest here that these later activities are related to a process for localizing sensory signals in space. Several lines of evidence show that our conscious sensation of touch is not necessarily localized to the skin. The sensation of touch can be referred, such as to rubber hands (Botvinick & Cohen, 1998) or phantom limbs (Ramachandran, Rogers-Ramachandran, & Cobb, 1995), or even to the surface of a desk (Ramachandran & Blakeslee, 1998), when concurrent vision of touching these items is available. Our recent study (Yamamoto & Kitazawa, 2001b) suggests that sensory signals can be referred to the tip of a stick held in the hand, even without concurrent vision of the touch. These studies suggest that our conscious experience of touch is not necessarily bound to the location of the mechanoreceptors that detect the touch, but can be referred flexibly wherever reasonable.

Extending this line further, I hypothesize that our conscious sensation of touch takes place in space rather than on the skin. That is, conscious sensation of touch is first localized in space to where the hand (and thus the particular part of the skin) is placed, before it is finally localized to the skin. In our recent study (Yamamoto & Kitazawa, 2001a), we suggested that the temporal order of two stimuli delivered in rapid succession, one to each hand, is determined *after* the stimuli are localized in *space*. If we assume that the two "conscious sensations" of touch are so ordered, our study (Yamamoto & Kitazawa, 2001a) strongly supports the hypothesis that conscious sensation is already localized in space. Assuming this hypothesis, it is no wonder that the primary positive evoked potential over the postcentral gyrus is not sufficient to produce conscious sensation because the initial activity in the primary sensory cortex is not yet linked with any information about the spatial location of the stimulus. I infer that our conscious sensation of touch is associated with activities outside the primary sensory cortex, such as those in the superior parietal lobe, where spatial hand positions are represented in the human brain (Wolpert, Goodbody, & Husain, 1998). Considering the latencies of 70–500 ms, it is possible that later components of the evoked potentials recorded in the primary sensory cortex are contributed by feedback inputs from these higher association cortices, where the sensory signals from skin might be localized to a point in space. Then how long does it take to localize the sensation of touch in space?

Observations of saccadic eye movements to somatosensory targets (Groh & Sparks, 1996) provide a good estimate. In their experiments, vibrotactile stimuli were delivered to the hands (somatosensory targets), which were concealed beneath a barrier. Interestingly, the trajectories of many saccades curved markedly when the arms were crossed; many saccades began in the direction of the wrong target and curved toward the correct one in midflight. The results indicate that the spatial position of the stimulus delivered to the crossed hand was not settled before the onset of the curved saccades, i.e., not before ~200 ms after the touch. When one subject was required to delay the saccade by 600–1000 ms after the touch, the saccades were straight. Thus the spatial location of a somatosensory target is settled during the period between ~200 and 600 ms after touch, and it takes more than 200 ms to correctly identify a sensation of touch in space, at least when the arms are crossed.

Pockett (2002) assigns a latency of 80 ms to a *simple* conscious experience. If such a simple conscious sensation is established at 80 ms, even when the arms are crossed, what would the content be? Let us consider four of the many possibilities: (1) The correct hand was touched. (2) The wrong hand was touched. (3) One of the two hands was touched, but which hand is not certain. (4) Both hands were touched, with weaker sensation. Considering the curved saccades, the first possibility is the least likely at 80 ms; however, by 600 ms after the touch, our conscious experience should converge on this possibility. Our conscious experience may therefore evolve over time, until it is stably localized in space.

Finally, I would like to emphasize the importance of investigating what is actually happening in the brain, not only in the primary somatosensory cortex but also in "higher" cortical areas, during the period 80–500 ms after a stimulus, as this holds the key to our conscious sensation.

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