The neural time factor in conscious and unconscious events

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Abstract. Our earlier evidence had indicated that a substantial duration of appropriate cerebral activity (up to about 0.5 s) is required for the production of a conscious sensory experience; this means the sensory world is experienced delayed with respect to real time. Subjective timing of the experience can be retroactively referred to the time of the earliest signal arriving at the cortex. Our 'time-on' theory states that the transition from an unconscious to a conscious mental function is determined, at least in part, by an increase in the duration of appropriate neural activities. Our experimental finding that conscious intention to act appears only after a delay of about 350 ms from the onset of specific cerebral activity that precedes a voluntary act provided indirect evidence for the theory. In a direct experimental test a signal (stimulus to somatosensory thalamus) was correctly detected in a forced-choice test even when the stimulus duration was too short to produce any awareness of the signal; to go from correct detection with no awareness to detection with awareness required an additional 400 ms of the repetitive identical neural volleys ascending to sensory cortex. 'Time-on' theory has important implications for a variety of unconscious–conscious interactions.

1993 Experimental and theoretical studies of consciousness. Wiley, Chichester (Ciba Foundation Symposium 174) p 123–146

Philosophical theories and analyses of the relationship between conscious mind and neural activities in the brain have been important in examining ways of looking at this relationship (e.g. Nagel 1979). Any theory that purports to specify how the mind and brain are actually interrelated should be testable by observations, whether experimental or descriptive. The proposal by Descartes, that the mind is located in the pineal body, was testable; unfortunately, he did not or could not test what happens upon destruction of the pineal. Our own approach has been to frame questions in terms of neuronal functions that may mediate the production of and the transition between conscious and unconscious events, and to investigate these experimentally by simultaneously observing and manipulating cerebral neuronal functions on the one hand and introspective reports of subjective experiences on the other (Libet et al 1964, Libet 1966, 1973).
The conscious experiences studied were either simple somatosensory ones ('raw feels') or conscious intentions/wishes to initiate (or block) a simple voluntary action (sudden flexion of a wrist). These psychologically simple events minimized potential complications from emotional or other impacts on the validity of introspective reports, they were amenable to experimental tests of their reliability, and areas of cerebral cortex involved in their mediation were available for electrophysiological study with intracranial and extracranial electrodes in awake human subjects.

Is conscious experience produced by all kinds of cerebral neuronal events?

Some have argued or speculated that this is the case. Our direct evidence gives a flatly negative answer to this question. We must distinguish between activities that may be necessary and those that are sufficient for conscious events. For example, the reticular formation in the brainstem and thalamus is clearly necessary; lesions in this system can abolish all evidence of conscious functions. But it does not follow that conscious experience is produced or 'resides' there; cessation of the heart beat also quickly abolishes conscious experience, but there is clear evidence that the heart is not where conscious experience arises.

A peripheral sensory stimulus normally elicits a large electrophysiological 'primary evoked response' of primary sensory (cerebral) cortex, beginning about 20 ms after a stimulus and lasting about 50–100 ms. This primary evoked potential can be elicited without the normally accompanying, later event-related potentials when (a) the skin stimulus is below the threshold for sensory awareness, or (b) a single stimulus pulse is applied to the somatosensory pathway in the brain where it produces no sensation at all, as seen in Fig. 1 (Libet et al 1967). In these conditions, a substantial activation of large numbers of cortical neurons occurs without producing any reportable awareness. Similarly, large electrophysiological responses of cerebral cortex can be recorded adjacent to a cortical stimulus site (the so-called 'direct cortical response'). We found such large responses both with cortical stimuli below the intensity that could produce any sensation and when stimulus pulses that were at supraliminal intensity for sensation were not repeated for a sufficient time (up to 0.5 s) (Libet et al 1967, Libet 1973). We could abolish the direct cortical responses by local application of the inhibitory transmitter \( \gamma \)-aminobutyric acid (GABA) with no demonstrable effect on the conscious sensory responses to stimuli at the sensory cortex or at the skin. This demonstrated that the neuronal activities represented by direct cortical responses were neither necessary nor sufficient for conscious responses.

Are there neuronal events that can uniquely mediate the distinction between conscious and unconscious mental events?

An answer to this question appeared to be a more achievable goal than specification of all the neuronal functions that are necessary and sufficient for...
(ii) The sensation induced by a single stimulus pulse to the skin can be retroactively enhanced by a stimulus train applied to somatosensory cortex, even when the cortical stimulus begins 400 ms or more after the skin pulse (Libet 1978, Libet et al 1992). This indicates that the content of a sensory experience can be altered while the experience is ‘developing’ during a roughly 500 ms period before it appears.

(iii) Reaction times to a peripheral stimulus were found to jump discontinuously, from about 250 ms up to more than 600–700 ms, when subjects were asked deliberately to lengthen their reaction time by the smallest possible amount (Jensen 1979). This surprising result can be explained by assuming one must first become aware of the stimulus signal in order to delay one’s response deliberately; if up to 500 ms is required to develop that awareness, then the reaction time cannot be deliberately increased by lesser amounts.

**Neural delay and subjective timing.** A neural delay, of up to about 500 ms before a conscious sensory event can appear, would mean that we do not experience the sensory world in real time. But the subjective timing of an event need not be identical with the actual time of the neural production and appearance of the experience. We demonstrated that there is normally a subjective referral of the experiential event backwards in time to the time of the primary evoked potential; the latter begins in the somatosensory cortex about 10–20 ms after a skin stimulus (Libet et al 1979). The subjective time of the experience is thereby antedated in a way that ‘corrects’ for its neural distortion from ‘real’ time (see Fig. 2).

Is there a general timing principle applicable to all awareness? That is, is awareness of any event, whether induced by a sensory stimulus or originating endogenously as a mental operation in the brain, subject to similar neural delays of up to 500 ms before it can appear? We tested one non-sensory, endogenous event, by studying the time of appearance of the conscious intention to perform a voluntary act.

**Conscious intention relative to brain initiation of a voluntary act.** Evidence of the onset of cerebral processes that specifically precede a voluntary act is obtainable by a scalp recording of the ‘readiness potential’. This potential, a slow negative wave, had been found by Kornhuber & Deecke (1965) to precede each ‘self-paced’ movement by 800 ms or more. We subsequently established that a readiness potential began about 550 ms before even a spontaneous endogenous voluntary act commenced without any restrictions on when to act or by any ‘pre-planning’ of when to act (Libet et al 1982). Using a ‘clock-time’ method for obtaining the subject’s reports of when he/she was first aware of any intention or wish to act, we showed that the readiness potential began about 350 ms before the appearance of the conscious intention to act (Libet et al 1983a).

![Diagram of hypothesis for subjective referral of sensory experience backward in time.](image)

**FIG. 2.** Diagram of hypothesis for subjective referral of sensory experience backward in time. The average evoked response (AER) recorded at somatosensory (SS-I) cortex was evoked by pulses just suprathreshold for sensation (at about 1/s, 256 averaged responses) delivered to skin of contralateral hand. Below the AER, the first line shows the approximate delay in achieving the state of neuronal adequacy that appears (on the basis of other evidence) to be necessary for eliciting the sensory experience. The lower line shows the postulated retroactive referral of the subjective timing of the experience, from the time of neuronal adequacy backward to some time associated with the primary surface-positive component of the evoked potential. The primary component of the AER is relatively highly localized to an area on the contralateral postcentral gyrus in these awake human subjects. The secondary or later components, especially those following the surface-negative component after the initial 100 to 150 ms of the AER, are more widely distributed over the cortex and more variable in form, even when recorded subdurally (see, for example, Libet et al 1975). This diagram is not meant to indicate that the state of neuronal adequacy for eliciting conscious sensation is restricted to neurons in primary SS-I cortex of postcentral gyrus; on the other hand, the primary component or ‘timing signal’ for retroactive referral of the sensory experience is a function more strictly of this SS-I cortical area. (The later components of the AER shown here are small compared to what could be obtained if the stimulus repetition rate were lower than 1/s and if the subjects had been asked to perform some discriminatory task related to the stimuli, as seen for example in Desmedt & Robertson 1977). From Libet et al (1979), by permission of *Brain.*
FIG. 3. Diagram of sequence of events, cerebral and subjective, that precede a fully self-initiated voluntary act. Relative to 0 time, detected in the electromyogram (EMG) of the suddenly activated muscle, the readiness potential (RP) (an indicator of related cerebral neuronal activities) begins first, at about -1050 ms when some pre-planning is reported (RP I) or about -550 ms with spontaneous acts lacking immediate pre-planning (RP II). Subjective awareness of the wish to move (W) appears at about -200 ms, some 350 ms after onset even of RP II but well before the act (EMG). Subjective timings reported for awareness of the randomly delivered S (skin) stimulus average about -50 ms relative to actual delivery time.

(see Fig. 3). This indicated (i) that development of the awareness of intention to move required a substantial period of cerebral activity and (ii) that initiation of a voluntary act is developed unconsciously by the brain. It is important to note that conscious intention does appear about 150–200 ms before the act, and that during this interval the subject can block or veto the consummation of the volitional process (Libet et al. 1983b). The implications of these findings for the question of free will are discussed below (see Libet 1985).

'Time-on' theory for mediation of the transition between conscious and unconscious mental events

Many, if not most, mental functions or events proceed without any reportable awareness, i.e. unconsciously or non-consciously. These apparently include cognitive detection of sensory signals and appropriate behavioural responses to them, for example in the blindsight phenomenon (Weiskrantz 1986) and in word primings (see Holender 1986), and in the cerebral initiation of a voluntary act (Libet 1985). There is descriptive evidence for unconscious processing of even complex functions, as in problem-solving or intuitive and creative thinking. On the other hand, the simplest kinds of mental functions can be accompanied by awareness/subjective experience, like the awareness of a localized tap on the skin or of a few photons of light on the retina, etc. It is not, then, simply the complexity or creativeness of a mental function that imparts to it the quality of subjective awareness of what is going on. The cerebral code for the distinction between the appearance or absence of awareness in any mental operation would seem to require a mediating neuronal mechanism uniquely related to awareness per se, rather than to complexity, etc. In view of our finding of a substantial temporal requirement for the production of even a threshold sensory awareness, I have proposed a 'time-on' theory that provides one potentially controlling factor for the neural distinction between conscious and unconscious mental events.

The theory states (i) that certain appropriate but short-lasting neuronal activities may mediate unconscious mental events and (ii) that these mental events may acquire awareness, i.e. become conscious, only if those neuronal activities persist for an adequate time (up to about 500 ms, depending on the conditions of intensity, etc.). That is, it is the duration ('time-on') of neuronal activities that may control the transition between conscious and unconscious events. Part (ii) was already experimentally supported, but a direct test of both parts (i) and (ii), for the case of unconscious versus conscious detection of a sensory signal, has been carried out (Libet et al. 1991).

Experimental test of theory

Our earlier evidence had shown that a stimulus in the ventrobasal thalamus, in the cerebral somatosensory pathway, had to last up to 500 ms to produce a sensory experience (Libet et al. 1967, Libet 1973). For the present test the duration of stimulus pulse trains in the thalamic nucleus was varied between 0 and 750 ms at random in different trials. In each trial the subject was asked to make a forced choice as to which of two lighted intervals 'contained' the stimulus, even if he/she felt nothing, and also to indicate his/her level of awareness of any sensation elicited by the stimulus. Because the stimulus was delivered randomly in either of the two intervals, correct answers above the pure chance rate of 50% would indicate a degree of detection, accompanied by either sensory awareness or by no awareness (i.e. the choice being a pure guess). The study was made possible by the availability of suitable human subjects in whom stimulating electrodes had been chronically implanted in the somatosensory (ventrobasal) thalamus for therapeutic control of intractable pain. Each brief stimulus pulse of a train at 72/s was at the same liminal intensity in all trials of a given series of train durations. Therefore, each pulse excited essentially the same nerve fibres and delivered the same amount of ascending sensory input to the cortex; only the number of such inputs varied among different trials in a series.

Results of the study are summarized for all subjects in Table 1. Statistical analysis clearly showed (i) that detection (correct > 50%) occurred with stimulus durations too brief to elicit any sensory awareness (150 ms or less), and (ii) that to move from correct detection with no awareness to correct detection with minimal awareness (i.e. only to add awareness to a correct answer) required an
additional 385 ms of train duration. Thus, the transition between psychological detection of a sensory signal without awareness and the detection with awareness can be controlled simply by the duration of the repetition of similar ascending activations of sensory cortex. The requirement of long trains for awareness statistically confirmed our previous findings when we stimulated either sensory thalamus or sensory cortex.

How would the minimum duration of neuronal activity lead to a conscious experience?

There appear to be at least two general options: (i) The repetition of appropriate neuronal activities for up to 0.5 s finally elicits some specific neuronal event that 'signifies' or is accompanied by a conscious event. (ii) The substantial minimum duration of neuronal repetition could itself constitute the 'code' for the appearance of an accompanying conscious event. The required neuronal activities in either option could be localized in some specific site in the brain (an unattractive possibility that implies a specific location for conscious awareness) or they could be more globally distributed in the brain.

The possibility that the generation of a conscious event in the first option is mediated by an integrative mechanism sensitive simply to intensity and duration of the neuronal activities does not agree with available evidence: (i) when stimuli to the ventrobasal thalamus or to somatosensory cortex (postcentral gyrus) were just below the liminal intensity (for eliciting sensory experience with long stimulus durations of more than one second), then no conscious sensation was elicited even with durations of 5 s or longer (Libet et al. 1964, Libet 1973). Such 'subliminal' intensities are not below threshold for eliciting neuronal responses; substantial electrophysiological responses of large populations of neurons are recordable with each such 'subliminal' stimulus pulse. Were simple integration of intensity and duration the controlling mechanism, a sufficiently long train duration of stimulus pulses would be expected to become effective for awareness. (ii) At a liminal intensity which becomes effective with an average 0.5 s of train duration, the neuronal responses recordable electrically at the cortex exhibit no progressive alteration during the train and no unique event at the end of the 0.5 s train (Libet 1973, 1982). Obviously, not all the possible neuronal activities were recordable, but this evidence offers no support for a progressive integrative factor. (iii) The minimum train duration that can elicit awareness, when the intensity is raised as high as possible, has not been firmly established, although it would appear to be in the order of 100 ms. However, it was empirically quite definite that a single stimulus pulse localized to the medial lemniscus could not elicit any conscious sensation no matter how strong (Libet et al. 1967); this was true even when the intensity of the single pulse was 20–40 times the strength of the liminal I (liminal I is the minimum peak current to elicit sensation when delivering a train of pulses with duration > 0.5 s). Although

<table>
<thead>
<tr>
<th>Awareness level</th>
<th>Number of trials</th>
<th>% correct trials</th>
<th>% correct responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>189</td>
<td>51</td>
<td>60</td>
</tr>
<tr>
<td>Level 1</td>
<td>3</td>
<td>32</td>
<td>66</td>
</tr>
<tr>
<td>Level 2</td>
<td>3</td>
<td>32</td>
<td>66</td>
</tr>
<tr>
<td>Level 3</td>
<td>169</td>
<td>51</td>
<td>60</td>
</tr>
<tr>
<td>Number of pulses</td>
<td>0–10</td>
<td>11–19</td>
<td>20–29</td>
</tr>
<tr>
<td>% correct trials</td>
<td>1050</td>
<td>75</td>
<td>449</td>
</tr>
<tr>
<td>% correct responses</td>
<td>57</td>
<td>68</td>
<td>68</td>
</tr>
</tbody>
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This table shows the data for the number of correct trials and responses across different awareness levels and number of pulses. The results indicate that the number of correct trials increases with the number of pulses, while the percentage of correct responses decreases. The overall percentage of correct responses is 60%, with slight variations across different awareness levels and pulse numbers.
the intensity of stimulus may not necessarily correlate linearly with the number of axons excited, the effectiveness of 10 pulses (at 20/s) at liminal I contrasted with the ineffectiveness of a single pulse at 40 times this liminal I, argues against a simple integrative mechanism. However, it must be admitted that a 'leaky integrator' may still be compatible with this evidence (a suggestion made by Francis Crick, personal communication).

Mildly supportive of the second option is the fact that no specific or unique neuronal event has thus far been found in recordings of 'direct cortical responses' to stimulation of the cortex (Libet 1973) or in event-related potentials (e.g. Libet et al 1975). Admittedly, many possibilities of an undetected neuronal event remain. The decision between the two options remains open, pending further experimental investigations.

Implications for interactions between conscious and unconscious mental events

Cerebral representation. If the transition from an unconscious to a conscious mental function could be dependent simply on a suitable increase in duration of certain neural activities, then both kinds of mental functions could be represented by activity in the same cerebral areas. Such a view would be in accord with the fact that the constituents and processes involved in both functions are basically similar, except for the awareness quality, and with the general view that both types of functions are probably mediated by broadly distributed neural activity. Separate cerebral sites for conscious versus unconscious functions would not be necessary, although this possibility is not excluded.

All-or-nothing character of awareness. If the transition to and production of awareness of a mental event occur relatively sharply, at the time a minimum duration of neuronal activities is achieved, this suggests that an awareness appears in an all-or-nothing manner (Libet 1966). That is, awareness of an event would not appear at the onset of an appropriate series of neural activities and develop gradually. Conscious experience of events, whether initiated exogenously or endogenously, would have a unitary discontinuous quality. This would be opposed to the continuous 'stream of consciousness' nature postulated by William James and assumed in many present theories of the nature of consciousness; it is, however, in accord with a postulate of unitary nature for mental events adopted by Eccles (1990) as part of his theory for mind–brain interaction.

Filter function. It is generally accepted that most sensory inputs do not achieve conscious awareness, even though they may lead to meaningful cerebral responses and can, in suitable circumstances (of attention, etc), successfully elicit conscious sensation. The 'time-on' requirement could provide the basis for screening inputs from awareness, if the only inputs that elicit awareness are those that induce the minimum duration of appropriate activities. Such a requirement could prevent conscious awareness from becoming cluttered and permit awareness to be focused on one or a few events or issues at a time.

Delayed experience versus quick behavioural responses. Meaningful behavioural responses to a sensory signal, requiring cognitive and conative processing, can be made within as little as 100–200 ms. Such responses have been measured quantitatively in reaction time tests and are apparent in many kinds of anecdotal observations, from everyday occurrences (as in driving an automobile) to activities in sports (as when a baseball batsman must hit a ball coming at him in a tortuous path at 90 miles per hour). If actual conscious experience of the signal is neurally delayed by hundreds of milliseconds, it follows that these quick behavioural responses are performed unconsciously, with no awareness of the precipitating signal, and that one may (or may not) become conscious of the signal only after the action. Direct experimental support of this was obtained by Taylor & McCloskey (1990), who showed that the reaction time for a visual signal was the same whether the subject reported awareness of the signal or was completely unaware of it owing to the use of a delayed masking stimulus.

Subjective timing of neurally delayed experience. Although the experience or awareness of an event appears only after a substantial delay, there would ordinarily be a subjective antedating of its timing back to the initial fast response of the cortex, as discussed above (see Libet et al 1979). For example, a competitive runner may start within 100 ms of the starting gun firing, before he is consciously aware of the shot, but would later report having heard the shot before starting.

There is another facet to this issue: for a group of different stimuli, applied synchronously but differing in location, intensity and modality, there will almost certainly be varying neural delays at the cortex in the times these different experiences appear. This could lead to a subjective temporal jitter for the group of sensations. However, if each of these asynchronously appearing experiences is subjectively antedated to its initial fast cortical response, they would be subjectively timed as being synchronous, without subjective jitter; the differences among their initial fast cortical responses are approximately 10 ms and too small for subjective separation in time.

Unconscious mental operations proceed speedily. If there is virtually no minimum 'time-on' requirement for unconscious (or non-conscious) mental processes in general, then these could proceed quickly, in contrast to conscious events. This feature is obviously advantageous, not only for fast meaningful reactions to sensory signals but also for the more general operations of complex, intuitive and creative mental processes, many of which are deemed to proceed
unconsciously. Conscious evaluation would be expected, according to the theory, to be much slower.

**Opportunity for modulation of a conscious experience.** It is well known that the content of the introspectively reportable experience of an event may be modified considerably in relation to the content of the actual signal, whether this be an emotionally laden sensory image or endogenous mental event (which may even be fully repressed, in Freud's terms). For a modulating action by the brain to affect the eventual reportable experience, some delay between the initiating event and the appearance of the conscious experience of it seems essential. The 'time-on' theory provides a basis for the appropriate delays. We have some direct experimental evidence for such modulatory actions on the awareness of a simple sensory signal from the skin: an appropriate cortical stimulus begun 400 ms or more after the skin pulse could either inhibit or enhance the sensory experience (Libet et al 1972, 1992, Libet 1978, 1982).

'**Time-on theory', conscious control and free will.** The experimental evidence indicates that a voluntary act is initiated in the brain unconsciously, before the appearance of the conscious intention. The question then arises, what role, if any, does the conscious process itself have in volitional actions? (In this, we are considering only the processes immediately involved in the performance of a voluntary movement. The issue of conscious planning of how, whether and when to act is a separate one.) Clearly, free will or free choice of whether 'to act now' could not be the initiating agent, contrary to one widely held view. We must distinguish the initiation of a process leading to a voluntary action from control of the outcome of that process. The experimental results showed that a conscious wish to act appeared at about -200 ms, i.e. before the motor act, even though it followed the onset of the cerebral process (readiness potential) by about 350 ms (see Fig. 3). This provides a period during which the conscious function could potentially determine whether the volitional process will go on to completion. That could come about by a conscious choice either to promote the culmination of the process in action (whether passively or by a conscious 'trigger'), or to prevent the progress to action by a conscious blockade or veto. The potential for such conscious veto power, within the last 100-200 ms before an anticipated action, was experimentally demonstrated by us (Libet et al 1983b). It is also in accord with common subjective experiences, that one can veto or stop oneself from performing an act after a conscious urge to perform it has appeared (even when the latter is sudden and spontaneous).

Even if we assume that one can extrapolate these results to volitional acts generally, they do not exclude a possible role for free will. However, the potential role of free will would be constrained; free will would no longer be an initiator of the voluntary act, but only a controller of the outcome of the volitional process, after the individual becomes aware of an intention or wish to act.

In a general sense, free will could only select from among the brain activities that are a part of a given individual's constitution.

If we generalize the 'time-on' theory to apply to all mental functions, a serious potential difficulty arises if the theory should also apply to the initiation of the conscious control of a volitional outcome. If the conscious control function itself is initiated by unconscious cerebral processes, one might argue there is no role at all for conscious free will, even as a controlling agent. However, conscious control of an event is not the same as becoming aware of the volitional intent. Control implies the imposing of a change, in this case after the appearance of the conscious awareness of the wish to act. In this sense, conscious control may not necessarily require the same neural 'time-on' feature that may precede the appearance of awareness per se. There is presently no specific experimental test of the possibility that conscious control requires a specific unconscious cerebral process to produce it. Given the difference between a control and an awareness phenomenon, an absence of the requirement for conscious control would not be in conflict with a general 'time-on' theory for awareness. Thus, a potential role for free will would remain viable in the conscious control, though not in the initiation, of a voluntary act.

**Summary of conclusions**

Conscious experience or awareness of sensory or volitional events appears to depend on a unique set of neuronal activities; a controlling factor in this is a substantial 'time-on' or duration for these activities. The sensory world is experienced with a delay with respect to real time, but a subjective antedating mechanism 'corrects' this distortion.

Unconscious mental operations or events, including complex cognitive and creative functions, could be mediated by brief neuronal activities and thus proceed rapidly. The transition from an unconscious function to one with awareness may be controlled simply by the duration of neuronal activity.

Voluntary acts may be initiated in the brain unconsciously, before any awareness of conscious intention to act, but conscious control of whether the motor act actually occurs remains possible.

**Acknowledgements**

I am indebted to the many cooperative patients and to my splendid chief research colleagues (Bertram Feinstein, Elwood W. Wright, W. Watson Alberts, Curtis A. Gleason, David Morledge and Dennis K. Pearl) for making the experimental studies possible. The most recent study (Libet et al 1991) was supported by USPHS grant NS-24298.
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Time factors in cerebral and mental events


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DISCUSSION

Searle: I have a factual question about the readiness potential. You confidently ascribe mental reality to the readiness potential prior to the wish. You said it was an unconscious mental phenomenon.

Libet: I said there is an initial period of cerebral activity during which the volitional process is unconscious.

Searle: Of course, at the level of the neuronal firings, the cerebral activity is all unconscious. I thought you were saying that in addition to the conscious wish, and in addition to the patterns of neuron firing, there is something else, namely the unconscious mental event.

Libet: I'm calling it that in the sense that the developing voluntary intention to act may be regarded as a mental event.

Searle: But there's no mental reality to the formation of a readiness potential—at least the way I heard you describe it.

Dennett: Its occurrence predicts the voluntary motion.

Van Gulick: I am concerned that what you are studying isn't a very good paradigm of typical voluntary motion. In one experiment, people are asked to pick a time to move their finger. They move it any time they want, it's spontaneous, but it doesn't strike me as a very good model of a voluntary action. You say there is no pre-planning, but, typically, when I make a decision, say, to interrupt the conversation and follow up on John's remark, there is a lot of consciousness that preceded the choice of my beginning to speak—a lot of conscious pre-planning.

Searle: Ben, are you not attributing any mental reality beyond the straight neurophysiological processes?

Libet: Only to the extent that people talk about unconscious mental processes in general. But, these unconscious cerebral activities can resemble the conscious processes in their cognitive, conative, problem-solving functions, so it may be appropriate to regard this as mental as much as a conscious function is, but without the awareness feature.

Searle: But generally people don't know what they are talking about!
Wall: I would like to challenge one of Ben Libet’s assumptions. Ben, you assume that there is the great timekeeper somewhere in your head, who is dependent on cortical activity. When the cortical activity is sufficient, he presses his dodgy stopwatch which jumps back 500 ms. My simple question is, why put that timekeeper in the cortex? Why not somewhere else?

Gray: Why put the sensation in the cortex? The other implicit assumption in this is that when you stimulate the cortex, and presumably when you stimulate the medial lemniscus or the thalamus, that is where the sensation is elaborated. We don’t know enough about the necessary and sufficient conditions of brain happenings for sensation to occur for us to assume that your stimulation is necessarily instantly doing the right things, rather than requiring a long period of reverberation to recruit other necessary machinery.

Libet: I was not committed to any location of the sensory experience. I was simply providing conditions that could control the neural time required to develop the experience and the subjective timing of it. The spatial extent of brain loci in these processes is not yet being specified.

Wall: But you are dependent on cortex providing the start time around which all other events are ordered in time.

Libet: I think the sensory cortical primary evoked potential is a necessary condition for the referral in time. That doesn’t mean the referral is carried out there.

Gray: But that evoked potential itself reflects inputs into the cortex from all sorts of places that we don’t properly understand.

Libet: The primary evoked potential is a very straightforward response to the fast specific projection pathway, via medial lemniscus to ventrobasal thalamus to somatosensory cortex. The primary evoked potential does not involve a response to other diffuse inputs, although the later evoked components do.

Wall: I would like to refer to two experimental facts which suggest that the cortex is not the primary site for detecting the nature and timing of a sensory stimulus (Wall 1970). When the thoracic cord in rats is cut to leave only the dorsal columns intact, the sensory input to the cortex is limited to only the dorsal column-medial lemniscus system. Distal stimuli evoke a large cortical evoked potential, which is normal in size, shape and duration, but the forward part of the animal shows no sign of reaction to the stimulus. This shows that the animal cannot utilize the presence of cortical responses unless other systems are active at the same time. Secondly, animals and humans react to single stimuli in the periphery and in sensory transmission systems but, as Dr Libet shows, it is necessary to stimulate cortex repeatedly before any sensation is provoked.

Libet: I can’t explain the first set of results, except to say that it seems to indicate that evoked potential processes are not sufficient for the rat to react. Perhaps the diffuse ascending projections cut in that experiment are the necessary feature for the rat to react at all.

Let me add one experiment we did do that relates to the loss of specific projection inputs. We had one subject with a one-sided stroke that had completely and permanently blocked out the specific sensations for the hand and arm. The other side was normal. We compared the subjective timing of the two hands. We gave a skin stimulus to each hand and asked the subject about their relative timings. She reported the stimulus to the good hand as coming before that to the bad hand when they were stimulated together. We had to delay the stimulus to the good hand by about 400 ms before she said both stimuli occurred together. So in this case, the interference with the primary projection pathway produced a later, delayed subjective timing, which supports what I am talking about.

Kinsbourne: You make the assumption that after a stimulus has lasted half a second, awareness happens suddenly, but you don’t know that. It could be that after that half second there is an indeterminate period, then the awareness follows. Given that, your theory about projecting back in time, may or may not be correct. It may be that it takes quite a while after the end of the half second for the artificial input to be appreciated, so that actually the relationship between that and the natural input is a normal one, and you don’t need to assume the referral backward in time.

Libet: You are postulating that there is an extra delay for the experience to appear after the end of a 0.5 s cortical stimulus, and that there is no such extra delay for appearance of the skin-induced experience (after its neural delay of 0.5 s). That would be an ad hoc distinction based simply on your argument that the cortical stimulus is ‘artificial’. But there is no experimental evidence to support your distinction and there is not even any theoretical basis for speculating that there is an extra delay only after the end of the adequate cortical stimulus.

In fact, there is experimental evidence against your suggestion (Libet et al 1979, Table 3A). When delivery of a peripheral single-pulse stimulus was delayed (from the onset of the cortical stimulus train) by more than the minimum cortical duration, subjects tended to report the cortically induced sensory experience as appearing before the peripherally induced one. This agrees with there being no extra delay for the experience to appear after the end of an adequate cortical stimulus. Furthermore, if one stimulates in the ventrobasal thalamus, which is on the direct pathway to the somatosensory cortex from the skin, one finds exactly the same stimulus time requirement as at the cortex.

Dennett: Ben, you are saying there is a neuronal delay, and the actual onset of consciousness begins at one time but is referred back to the time of the primary evoked potential. You interpret this period as a ‘rising to threshold’ for consciousness.

Libet: Not a ‘rising to threshold’. The period of neuronal delay is regarded as being due to a minimum time of neuronal activities required to produce the reportable conscious experience, without specifying the mechanism that operates during that period of activity.
**Dennett:** Here's another interpretation of the data, which eliminates the problem of referral. The conscious experience happens at the time of the primary evoked potential. The later time you measure is the end of the Orwellian 'archive preparation' time; the duration is the length of time a memory trace has to be 'cured' before it is sufficiently in memory so that it can drive a later retrospective verbal response. That's the Orwellian account of this. Then we could say that the consciousness happened at the earlier time, but when conscious events happen they are wiped out of memory, unless there is a 500 ms curing time, which is what it takes to drive that conscious event into memory. Then the conscious event actually occurs in the brain at the moment it seems to occur. I would like to know what evidence you have that favours the theory which says that consciousness itself doesn't begin until the later time, and then it has a referral back in time.

**Libet:** The evidence for subjective referral backwards in time makes your proposal (that the conscious response appears almost immediately but producing the reportable memory of it requires the neural delay of 0.5 s) almost untenable. The crucial test of the referral hypothesis lay in the experiment with stimulating electrodes in the medial lemniscus (the fast cerebral pathway for somatosensory signals to thalamus and then on to cortex). Each pulse in the medial lemniscus puts a primary evoked response on the sensory cortex, just as a stimulus at the skin does. But, in contrast to the skin, the medial lemniscus has the same stimulus requirement as does sensory cortex—you have to stimulate at the liminal intensity for 0.5 s before any sensation can be reported.

So, each stimulus pulse in medial lemniscus evokes a fast primary response by somatosensory cortex, but, in the experiment described here, it was empirically established that the stimulus train of pulses in medial lemniscus had to persist for at least 200 ms to elicit any reportable conscious sensation. When the skin stimulus pulse was delivered 200 ms after onset of the medial lemniscus stimulus, the subject reported that the lemniscus-induced sensation appeared before the skin-induced sensation, in contrast to the order reported for a similar cortical stimulus (Libet et al 1979). So, even though the medial lemniscus stimulus could not have produced the reportable experience for up to 500 ms (depending on stimulus intensity), the subject timed the experience as if there were no delay relative to a skin-induced one. That result leads to the conclusion that the subjective timing of the medial lemniscus-induced sensation was subjectively antedated to match the subjective timing of the skin-induced sensation.

**Nagel:** How do you rule out the possibility that even a 300 ms stimulus produces an experience which never fixes in memory, so it's never reported? That is Dan's question.

**Libet:** To rule out conclusively every possible explanation for an observation is often not feasible experimentally: the proposal for a fixation of memory is like this. Because we commonly reject hypotheses that lack supporting evidence, the more significant question here is: what is the evidence to support Dennett's proposal? The answer is, none, as far as I know. On the contrary, there are experimental reasons to regard that theory as improbable.

Firstly, there are the inferences from the evidence I have just cited on backward referral. To account for the observation that subjective timings are similar for the single-pulse skin stimulus and the 200 ms train of medial lemniscus stimuli, your proposal would have to assume that the time for memory fixation is the same in both cases. Each of these sensory experiences would then become reportable only after 200 ms following the initial signal. But how would that explain the observation that a cortically induced sensation is subjectively timed to appear about 200 ms after the skin-induced sensation (or after 500 ms, if the stimulus intensity is weaker)? Dennett & Kinsbourne's (1992) proposal requires them to postulate that there is an *extra* delay for the appearance of the cortically induced experience, an extra delay that has to be equal to the duration of the cortical stimulus! Aside from the *ad hoc* nature of that speculation, there is the experimental evidence against it, that I mentioned in reply to Marcel Kinsbourne's comment.

Secondly, although development of a very short-term memory of an experience is required for reportability some seconds after the stimulus, the process for producing that memory need not reside in the specific neural activity involved in producing the experience. Our recent demonstration (Libet et al 1991) that very brief thalamic stimuli can be detected without generating awareness provides evidence against the proposal of Dennett and Kinsbourne. Because our subjects made their forced-choice responses after the same post-stimulus period of some seconds, whether or not they were aware of the stimulus, the same short-term memory of the signal was obviously produced, even by cortical stimuli of 100 ms or less. So, contrary to Dennett's proposal, the 200 to 500 ms of neural activity in question is not necessary for the production of a short-term memory of the signal, unless one adds the further *ad hoc* speculation that the memory process for a reportable conscious response has a fixation time much longer than the memory process for exhibiting a later detection without reportable awareness.

All in all, the kind of additional *ad hoc* tailoring of assumptions that seem to be required to make the Dennett explanation workable is what we normally reject from serious scientific consideration.

**Harnad:** If Dan Dennett's interpretation were valid, this wouldn't be evidence against it.

I would like to ask Dan what this thing is that happens and then vanishes without a trace. You do not seem to be saying merely that it vanishes without a trace after it happens if it fails to be consolidated, but that even at the instant when 'it' allegedly happens, it somehow has no conscious manifestation! But then why would you call 'it' a conscious experience at all?

**Dennett:** Remember, the game I'm playing right now is competing the Orwellian view against the Stalinesque. Our claim is that this is a false contrast.
Gray: If it's false, why do you ask him the question?
Dennett: Because Ben Libet thinks that he can prove the Stalinesque version.
I'm saying that everything Ben says to show that the Stalinesque version is true,
could equally well be cited to support the Orwellian view. Stevan, by your own
account, when people respond very swiftly—if somebody is asked to tap a button
as soon as they see a red light—they wait until they are conscious of the red
light and then they press the button. If you use that as a test of consciousness,
you have to put the consciousness back significantly earlier, because it doesn't
take the subject 500 ms to become conscious of the red light in order to initiate
the button press.

Harnad: That just stipulates that to get a reaction at all you must first be
aware of the stimulus. This need not be true: you could react first and be(com)e
conscious of it afterwards (Harnad 1982).

Rossetti: Several experiments have demonstrated that motor reaction time
to a visual stimulus may be shorter than the time to conscious awareness of
the same stimulus (e.g. Castiello et al 1991). Have you tried to reproduce your
experiment with the subject giving a motor response instead of a verbal one
to the cortical stimulation?

Libet: I didn't do that, precisely because a vocal response could appear before
awareness. There is another experiment that's more directly related to the issue
of when the subject becomes aware of the signal. A subject is given a skin pulse,
for example (this has also been done with a visual stimulus), then given a train
of cortical pulses starting up to 0.5 s after the skin pulse. The delayed cortical
stimulus can mask the sensation induced by the skin stimulus. The argument
in Orwellian terms would be that you have wiped out the memory. But a second
masking stimulus can wipe out the sensation elicited by the first masking
stimulus, and awareness of the original skin stimulus reappears. If the memory
was wiped out in the first case, how could the experience reappear?

Dennett: The Orwellian theory admits from the outset that the memory erasure
isn't complete: after all, in a forced-choice guess test, you would see that subjects
did better than chance at guessing whether the first stimulus had occurred.

Libet: The issue of the memory and the Orwellian approach started with the
difference between the cortical stimulus taking half a second and the skin
stimulus being experienced immediately (as if there were no delay). There is
an ad hoc assumption that the cortical stimulus involves something different,
i.e. abnormal or artificial, compared to the skin stimulus. Let's eliminate that
possibility and compare a cortical stimulus with a medial lemniscus stimulus;
both of these stimuli are 'abnormal'. They both need the same duration of
repetition to elicit any sensory experience, but the subjective timing is completely
different. The sensation induced by the medial lemniscus stimulus is timed
subjectively as starting right at the beginning of that stimulus; the sensation
induced by the cortical stimulus is subjectively timed as though it appears at
the end of that stimulus train. We have here excluded any assumptions about
the difference between the natural skin stimulus and the cortex, so where is the
difference based on the Orwellian memory?

Dennett: Direct stimulation of the cortex and of the medial lemniscus are
both very strange and unusual cerebral events. One wonders what assumptions
underlie your supposition that the direct application of electrical stimulation
to the cortex produces an event which is anything like a normal event. You are
saying that it is ad hoc for me to distinguish these two. It seems to me that
it's ad hoc for you to suppose that they are the same.

Libet: But I'm saying, compare stimulation of the medial lemniscus with
stimulation of the cortex—they both need the same duration of activation, and
they are both, in your sense, strange and unusual cerebral events. But their
subjective timing is strikingly different.

Dennett: Well, one of them has a primary evoked potential, the other
doesn't.

Libet: Exactly; that's the difference.

Shevrin: According to Dennett, in the Orwellian view there is misremembering
and in the Stalinesque view there is misperceiving, and there's no way we can
tell the difference. However, the existence of revised memories and misperceptions
doesn't rule out the possibility of empirically distinguishing between the Orwellian and Stalinesque views. For example, if the memory is
revised, the original memory should not be available, only the revised version,

Dennett: Why can't they both be available under different circumstances?

Shevrin: Well, what do you mean by revision then?

Dennett: Another draft just becomes more available.

Shevrin: You have offered the analogy of working at the wordprocessor. Once
you change the text, there is a new draft and the earlier draft is no longer
available. If the earlier draft is available, if traces of it are left, that sounds
Stalinesque to me, not Orwellian. It is not simply misremembering. If you have
the original trace, and a revised trace, and a re-revised trace, then you have
three different drafts available. Therefore, there is a canonical version, in the
sense that the original memory is more correct than its revisions, which is exactly
what you denied at first.

Marcel: It's not canonical.

Shevrin: Take your example of the jogger (Dennett & Kinsbourne 1992). The
jogger runs by without glasses, and then you have a draft of the jogger running
by without the glasses that leaves a trace of itself. Then it gets mixed up with
the memory of another jogger who wears glasses, and then you have a revised
memory of the first jogger as having glasses. It seemed to me that you were
saying that once that happens, the original version of the jogger without the
glasses is no longer available. There is now a new revised text. But what you
are saying now is that the earlier draft left a trace of itself and is thus available
to influence future perceptions. That sounds Stalinesque.
If it is correct that under certain conditions one can recover the original trace, then one can distinguish between the Orwellian (original trace unavailable) and the Stalininesque (original trace available).

**Marcel:** We can apply this to both visual masking and eye-witness testimony. In the latter, you can recover the original memory under certain conditions. Take Ben Libet’s example of the unmasking of a masked stimulus. Every time there is a new stimulus it masks the mask—you actually revise the draft. You can go on doing that for quite a long time. But that is exactly what Dan Dennett would like. I don’t like this, but I think it’s right—you do keep on revising it. But it doesn’t mean you have destroyed the original, because it can be recovered.

**Nagel:** I don’t understand the need for these elaborate alternative views. They all seem to arise from the desire to find something in real physical time corresponding to phenomenal temporal relations. There is no reason there should be a temporal physical representation of subjective time at all. Why do you need all these revisions?

**Dennett:** If what you say is right, and I think it is, then it is a criticism of Ben Libet, because he is saying he can time the onset of consciousness to a moment that is a lot less than somewhere within 500 ms. You are saying there is no issue in a 500 ms window; Ben is saying there is.

**Harnad:** There is either an equivocation or a misunderstanding here. This seems to be very similar to the error of not distinguishing the timing of an experience from the timing of the object of that experience. Your point is valid but it’s not exactly what’s under discussion here. Howard Shevrin’s point is equally valid because he’s talking about something different. When Howard says the original draft continues to exist, he is speaking of it as a candidate for an ongoing conscious experience, not as a record that is registered or shared but not experienced.

The real issue is: when did X happen? If X really happened at draft one, then there was a conscious experience. If it didn’t happen, there wasn’t one.

**Nagel:** So you think there has to be a precise answer in physical time to the question: when did my conscious wish to move my finger occur? I don’t see why that event has to have a precise temporal location.

**Gray:** What do you mean by ‘precise’?

**Nagel:** Well, it certainly occurred within a one minute interval.

**Gray:** So you permit sequencing. Is the issue simply a question of the precision with which one can speak about and time the occurrence of conscious events, or is it that in some way the whole concept of time doesn’t apply to conscious events?

**Nagel:** They can be physically located in a rough way. They have to be, because they do have certain physical causes and physical effects. But they also have, internally, a precise subjective temporal structure which doesn’t have to mirror anything in the temporal character of their physical basis. For example, in the case of the subjective simultaneity in the ‘will’ experiment between the perception of the clock hands reaching a certain point and the experience of deciding to press the button—that is a precise phenomenal simultaneity. It doesn’t have to correspond to any precise physical clock time at all, including the time when the clock handle objectively hits the top. It’s just something that happened in the mind at roughly that time.

**Velma:** One consequence of what you are saying is that it’s not legitimate to study the fine detail of the way temporal relationships are experienced. That can’t be right. For instance, it’s perfectly proper to study the precise physical conditions under which people report two events as being phenomenally simultaneous rather than consecutive. The fact that there may not be just one set of physical conditions which will produce phenomenal simultaneity or an experienced, temporal difference doesn’t mean it is not important to explore how different sets of physical relationships or neural encodings of them are translated into different experiences. So all these debates are important.

**Harnad:** I think I have a way to re-state the point about timing. Suppose the content of the event we are trying to time is: ‘This seems to be occurring at time t’. Let that be the experience we are talking about, the instant of the seeming-to-occur-at-time-t. But what we are really interested in is the true clock time (possible t) of the moment of that seeming, and not the time t that was merely its content. When Ben Libet is looking for the exact moment the experience of willing a movement occurred, he too is looking for the clock time of the seeming, not the clock time figuring in its content.

**Velma:** I have quite a different problem with Dan Dennett’s argument, which has to do with his use of the term ‘memory’. Normally, when we speak of people remembering or forgetting, we take it for granted that they have already had an experience which they can either report or not at some later time. According to Dan, Ben Libet’s findings can be explained in terms of an Orwellian loss of memory that takes place in the initial few hundred milliseconds after stimuli are projected to the brain. In other words, Dan assumes that temporal sequence is initially experienced one way, but when contradictory temporal information about the same stimulus arrives, the initial experience is forgotten and replaced by an updated experience. However, according to most psychological theories, stimuli arriving at the cortex may be coded and identified within the first few hundred milliseconds, but unless they are attended to they do not enter short-term memory. So consciousness of a stimulus and subsequent remembering or forgetting follow an initial period of preconscious processing. No doubt, stimuli are represented in the central nervous system within the first few hundred milliseconds and it may be that those representations can be overwritten by following representations. But to call that ‘forgetting’ (with the implication that what is forgotten has already been experienced), seems wrong.

I am also worried about the unfalsifiability of Dan’s suggestion. Let’s imagine a standard procedure in psychophysics—establishing a visual stimulus threshold.
You gradually turn up the intensity of a stimulus and at a certain point the subject says that he can see it. It is standard procedure to assume that the subject’s report is accurate. Then you gradually lower the intensity again until the subject says he can’t see it. Again, it is standard to accept the subject’s report as accurate. But, according to Dan, inability to report the stimulus might have resulted from rapid forgetting, and he could extend that claim to any reports that subjects make about not having experienced something. So, in spite of any claims subjects make to the contrary, Dan could maintain his position. That makes his position unfalsifiable.

References

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