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On Libet's experiments

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Summary

Background and aim*: In his experiments, Libet studied the time of the onset of conscious events and the time of neuronal activity associated with these events. The paper discusses interpretations of Benjamin Libet's experiments on the relation between neuronal activity and consciousness.* ***Material and method****: A comparison is made with other experiments by Hans H. Kornhuber and Lüder Deecke and Libet's findings are described and discussed in detail.* ***Results and conclusion****: In the comparison and taking into account other experiments the role of consciousness in initiating actions is much greater than judged by Libet.*

Key words: Libet, consciousness, subconsciousness

In his experiments, the neurophysiologist Benjamin Libet, now a Professor Emeritus at the School of Medicine of the University of California at San Francisco was interested in determining the time of the onset of conscious events and the time of neuronal activity associated with these events. He wanted to measure a correlation between activity of the brain and activity of the mind. Libet's experiments received wide attention[1] since they purportedly have far reaching philosophical, moral, and theological consequences.

The goal of the first experiment performed by Libet and his colleagues [2] was to test the timing of sensory consciousness: when exactly do we become aware of a sensory stimulus? Because there is no method to determine the absolute timing of a subjective experience, an experiment was set up to compare the subjective timing of different experiences. Libet measured a subjective timing of the conscious sensations of the skin caused by three different stimuli. One stimulation was applied to the somatosensory (SI) cortex (C), that is, the part of cortex that is responsible for skin sensation. Another simulation was applied to the subcortex, to the medial lemniscus (LM), which is "a tract carrying sensory information through the brainstem to the thalamus, whence it is relayed to the somatosensory cortex." Finally, one stimulus was applied directly to the skin.

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Libet established in previous experiments that a train of stimulus pulses (electric shocks) applied for 0.5 sec at liminal (minimum threshold) level to SI cortex or LM

[1] Cf., for example, Libet's 1985 paper in *Behavioral and Brain Sciences* [1] and the many accompanying comments; a 1992 special issue of *Revue de Metaphysique et de Morale*; a 1999 special issue of *Journal of Consciousness Studies*.

is required to elicit a conscious sensory experience. This time was used as a reference for stimuli applied directly to the skin. That is, 0.5 sec should be expected to elapse from the beginning of the skin stimulus to the beginning of sensation (the time required to reach the sensory cortex by nerve impulses from the skin is negligible, ca. 15 ms). But an increase of the stimulus intensity required shorter trains. In the experiments, a train of pulses, usually 60 pulses per second, was used with the maximum intensity required for a 200 msec train duration to cause a conscious experience. One pulse was sufficient to elicit a skin sensation.

The experiment was conducted on unanaesthetised patients in conjunction with neurosurgical treatment, which was possible because there are no pain receptors in the brain. Trains of stimulations by electrodes implanted in postcentral cortex indicate that there is a half a second delay after the beginning of the train; during this delay cortical activity reaches "neuronal adequacy" to evoke a conscious sensory experience. There is a similar delay for subcortical stimulation trains. Also, a similar delay exists when a single pulse is applied directly to the skin of the hand on the side opposite to that in which a sensation was caused by the cerebral stimulus.

In the experiment, two stimuli were applied to elicit sensations on the skin of both hands. However, the stimuli were applied in different combinations: skin-skin (directly to the skin of both hands); skin-LM (one stimulus to the skin and one to LM corresponding to the other hand), and skin-C. The stimuli were applied at the same time and with time delay, when the first stimulus was applied earlier (or later) than the second. In this way, the subject could compare whether the sensations were felt simultaneously, and if not, which sensation on which hand was felt first.

The expectation was that, for example, when skin stimulus and the cerebral stimulus were applied at the same time, sensations on both hands should also be experienced at the same time. However, it was not so. The skin stimulus was experienced subjectively within 10-20 msec after it was given. It is similarly with the subcortical stimulus. However, the cortical stimulus was experienced when expected, 200 msec after the stimulus train started. The timings of cortical, subcortical and peripheral (directly to

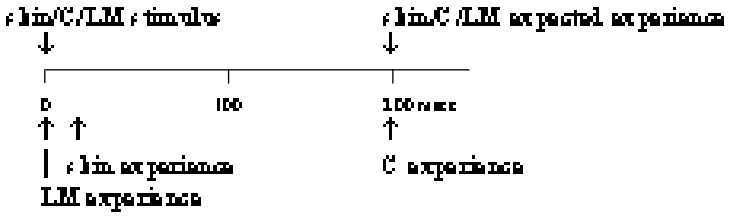

Figure 1

the skin) stimuli are indicated in this diagram:

The diagram indicates that the cortical stimulus was felt when it should have been, after 0.2 sec, when the train of stimuli ended, but both subcortical and skin stimuli were felt at the start of the stimuli. That is, the subjective experience induced by the

LM stimuli was referred to the beginning of the stimulus signal, not its end, but for the C stimuli, the experience was at the end of the stimulus train[2]. Libet says that the reason for this difference is the existence of "a subjective temporal referral of sensory experience" whereby the experience is antedated to the start of the stimulus that elicited the experience. Is it true that antedating "involves imputing something very like certain self-contradictory beliefs to subjects," as sometimes suggested ([5], 124)?

Consider vision. The image of an object in front of an eye appears upside down on the retina because of the way light rays reflected from the object are bent by the cornea and the lens, and yet we see the object right side up because the brain learns how to see the world right side up. Is it self-contradiction? The image is inverted but it is perceived as non-inverted in accordance to the objective situation. Also, consider vision and hearing at the same time. Light travels significantly faster than sound, but, as Poppel indicated, within a horizon of simultaneity of ca. 10 meters, light and sound appear to arrive at the same time from the same point ([6], Ch. 4). This is accomplished by antedating sound (or post-dating light) stimulus. It is similar with antedating of sensory experience on the skin. The experience can be sensed 0.2 sec after stimulus, but it is sensed as if it occurred concurrently with the stimulus. Is the mind deluding itself? The mind's task is to reflect the objective situation and it is accomplished by antedating. Although, physiologically, a sensation can be felt 0.2 sec after stimulus, to the subject it appears that no time elapsed between the two, the stimulus and the sensation. The mind is not deluding itself but righting, so to speak, an inadequacy of neuronal adequacy that lags behind the cause. The mind takes this time lag into account and reflects the real situation by linking the effect (sensation), directly with the cause (stimulus).

Admittedly, there is something curious about this process. Because of antedating, the sensation experience now feels like a sensation 0.2 sec before it happens. This is the problem of subjectivity of time. The antedating experience is not significantly different from the perception of the flow of time. It appears sometimes to us that time flies when we are surprised that it is already such-and-such hour, although we expected the hour to be earlier. Or it may seem to us that time drags when at such-and-such hour we are surprised to see, on the clock, time to be much earlier than it was expected to be. The mind is active in shaping our experience, after all, and Kant was not altogether mistaken in that respect. But Kant renounced any statements concerning time and the causal connection in the thing in itself. The antedating experience seems to indicate that to reconcile physiological limitations of the brain (neuronal adequacy) with plac-

[2] The subjective timing of the sensory experience caused by skin and subcortical stimuli are similar since "unlike SI cortex, each volley in LM [or skin] … should generate a primary evoked response in SI cortex," and the stimulus train applied to SI cortex "does not elicit a response resembling the primary evoked potential, presumably because it does not initially excite the ascending projection fibers … responsible for this response" ([3], 76); the cortical stimulus "did not excite the fast ascending nerve pathway (which enters from below the cortex), hence no subjective antedating occurred," but "stimulating the specific ascending pathway at a subcortical site of the brain (i.e., at medial lemniscus) did result in subjective antedating" ([4], 184).

ing effect as close to cause as possible in time, the mind uses Kantian time to reflect Einsteinian (or, for practical purposes, Newtonian) time. Subjective illusion is used to overcome physiological hurdles and better reflect an objective situation.

2

In early 1960s, Hans H. Kornhuber and Lüder Deecke conducted an experiment in which they asked their subjects to repeatedly flex a finger to press a button whenever they liked to [7]. They found that in the secondary motor area of the cerebral cortex there was a steady increase of the (negative) electric potential before an action was undertaken, which was called *Bereitschaftspotential* (BP), or readiness potential.[3] For complex movements (speaking, writing, calculating or drawing), BP begins 1-2 sec or even 3 sec prior to the start of movement. For brisk flexions of the right index finger, the average of over one thousand self-initiated movements indicated that the preparation took 1.5 sec before the action took place. To be more precise, the early component of BP, BP1, begins 1.5 sec to 1 sec (typically, 1.2 sec) before movement onset, indicated by a shallow (negative) slope; the late component of BP, the BP2, typically begins 0.5 sec before movement onset and is indicated by a steeper (negative) slope. BP1 is generated primarily by the mesial prefrontal cortex, BP2 by the primary motor cortex. That is, BP has two components with different timing features and different neuronal sources. The presence of BP was confirmed with other methods: MEG, magneto-encephalogram (where the equivalent of BP is called the *Bereitschaftsfeld*, readiness field), and SPECT [9].

In Kornhuber-Deecke's experiment, the brain displays preparatory activity a second before the muscle activity of the finger, which apparently indicated that the brain is getting ready to execute the action before the subjects *wanted* to do that, that is, the brain seemingly is preparing for an action before the subject consciously intends, makes a decision, to execute it.

There was a concern that Deecke-Kornhuber's experiments may have compromised the fully voluntary nature of the acts (for example, repeating the acts hundreds of times for averaging purposes imposes a limit on time in which to perform the act and introduces a strong component of boredom). Moreover, to distinguish between preparation to movement and a change of attentiveness as the process underlying BP, passive test of skin stimulus replaced the active test of finger movement [10].

Libet repeated the experiments with an addition designed to time more directly the moment of making the voluntary decision; they asked the subjects to state the clock position (the position of a spot of light revolving on the screen of an oscilloscope, making a complete circle in 2.56 sec) at the instant when the decision to flex the finger (or wrist) was made (clock position "in relation to performing the self-initiated act" ([10], 325). The subjects were asked to recall the clock position several seconds after the event. The self-initiated act test was accompanied by two tests. First, a pre-set act

[3] The presence of the contingent negative variation, the prolonged negative potential over the frontal lobes, is described for the first time in [8].

test in which the time limit was set at which flexing should be done. Second, a control test, a skin stimulus test, in which the time of stimulus on the hand (instead of voluntary finger flexing) and the time at which the subject experienced the stimulus were recorded. Because of the more stringent conditions, Libet et al. called the results self-initiated BPs (no limitation on time in which to perform a task; "no blinking" option not as rigorous; each trial was initiated as an independent event), to distinguish them from Deecke-Kornhuber's self-paced BPs. Three types of BPs were recorded: type I BP, gradually rising, ramp-shaped, onset at -1050; type II, dome-shaped, at -575; type III, at -240 ([10], 325, 333-334). On the average, the W time, that is, the time reported by the subject at the earliest awareness of intention (will) to flex the finger, was 200 msec before the act ([11], 629; [12], 263):

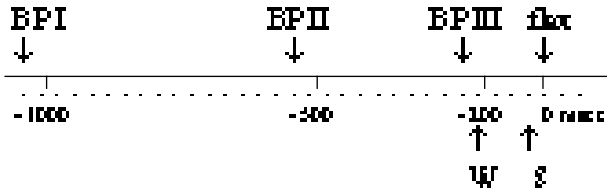

Figure 2

This diagram corresponds to a fully self-initiated voluntary act. The 0 point is indicated by the onset of the electromyogram (EMG) of the activated muscle.

Types I and II correspond to BP1 and BP2, respectively; type III BP has no counterpart in self-paced BPs ([10], 332). As expected, for skin simulation acts, there was almost no event-preceding potential shift. Self-initiated acts were associated with type II BP; pre-set acts, in which the voluntary choice of when to act was eliminated but planning to act was still required, were associated with type I BP.

Skin stimulus S was used in the control experiment to learn the accuracy with which subjects reported the time of the moving spot. The time for S was expected to be very close to time 0, time of actual application of the stimulus or slightly delayed. However, the time for S was usually negative: the recorded values for S for six subjects ranged from -167 Ř 28 to +83 Ř 17 (-167, -111, -40, -20, +46, and +83) ([10], 330), which may indicate that most of the time, the skin stimulus was felt before it was delivered. Libet simply states that "the bias or error found in the S series did not qualitatively alter the difference between onset of BP and W" ([11], 638), which may, but does not necessarily have to be the case. At least, this sheds some doubts upon the reliability of the timing method used to elicit reports about the onset of conscious events. "If the subject cannot tell when something as determinate as a skin stimulus happened then what hope has he got of giving the precise time at which an intention formed?" ([13], 338).

The first conclusion drawn by Libet from this experiment concerned the existence of two volitional processes: process I associated with general intention or preplanning; and process II, associated with a specific intention to act ([10], 328-330, 333-334). General intention is defined as "intention to act at some loosely defined time ap-

proaching in the near future; it can begin one or more seconds before the act" (p. 333). General intention was "most often" reported in some self-initiated acts as "a general intention or anticipation of performing the act during a forthcoming period of time, when the moving CRO spot would have entered a specific portion of its revolving circle (e.g., between 12 and 6 o'clock)" (p. 329). By the nature of the pre-set motor acts experiment, general intention concerned action within some time confines. This indicates that this general intention is not too general, which allows Libet to say that general intention is not always present ([10], 329-330; [11], 635). However, it seems that something more general than general intention should also be distinguished, which can be termed contextual intention[4]. In the case of Libet's experiment, contextual intention is simply the awareness that the finger has to be flexed - with no reference to temporal restrictions - which the subject knows after explanation of what he should do during the experiment. Certainly, the subject cannot lack this kind of contextual (very general) intention, otherwise, how could he flex the finger and not perform any other act? Therefore, contextual intention is always present, whether the experiment concerns pre-set acts or self-initiated acts; general intention (preplanning), however, may be absent from pre-set acts, but, still, the specific intention should be viewed in the light of the contextual intention. Why do subjects flex fingers? Because they planned that action, and then they waited for an urge to occur, the urge circumscribed by the plan. The will to act was there all along as an expectation to act, as being prepared to act, as a contextual intention. This contextual intention controls the triggering neuronal mechanism that later is manifested as specific intention, an intention to make this particular move. It is just like contextual intention of going to the store which triggers the neuronal and muscular mechanism for walking which is manifested by an awareness of walking; this awareness may succeed the first steps, but, nevertheless, the subject is certain that he initiated walking.

The second conclusion made by Libet is that consciousness is excluded from initiating spontaneous acts. They are initiated subconsciously, and consciousness has at best an illusion of initiating them. However, because there is still some time (200 msec) between W and the beginning of an act, consciousness can veto the decision of subconsciousness and thereby participate actively in the process of executing the act.

However, the subjects were encouraged "to let the urge to act appear on its own at any time without any pre-planning or concentration on when to act" in order "to elicit voluntary acts that were freely capricious in origin" ([10], 324). In other words, the subject should himself be surprised by the appearance of the urge. His role in the process was not to willingly elicit the act but willingly not to create any obstacle to an arising urge. And an urge, by its nature, is beyond the scope of consciousness.[5] It

[4] Libet sometimes appears to have such a general meaning of general intention when he distinguishes "general intention to act" - with no reference to temporal limitations – from "specific intention to act now" ([4], 183-184; [11], 635-636). In a conference he also remarked that "the actual initiation of volition may have begun even earlier [than 0.3 sec before the act] in a part of the brain we weren't monitoring" ([14], 234).

[5] Dennett and Kinsbourne correctly remark that Libet approximates in this experiment the *acte gratuit* depicted by Andre Gide in *Les caves du Vatican*, a purely motiveless choice, which hardly is a paradigm of "normal voluntary actions" ([15], 198).

arises subconsciously and then the subject becomes aware that it is there. Therefore, the W time is not when the subject wanted to flex the finger but when he become aware that the subconscious urge became conscious. The subject is willing to accept that the urge arose on his own volition because it is precisely what the subject wants in this experimental setup. The subconscious is responsible for the emergence of the urge, but the subconscious is here a subsidiary of consciousness; therefore, the statement that "cerebral initiation even of a spontaneous voluntary act … can and usually does begin unconsciously" ([11], 640) is not altogether convincing. The subject knows at the contextual intention level what he wants to accomplish: flex the finger at a random time, and then consciousness submits the expectation to the subconscious which takes care of the physiological details of the acts.

The reason for this situation is that consciousness can process up to 50 bits/sec of information at a time, whereas the amount of information that a person receives through the senses is immensely large in comparison, namely 10^7-10^8 bits/sec.[6] Therefore, consciousness is a strategist that leaves implementational and logistic details to subconscious mechanisms that are already in place. No particular concentration is needed to flex the finger properly, and this conscious concentration is even less needed when it is expected that an urge to move should be produced at a random time. This randomness is achieved best when consciousness does not participate in producing it. However, still, consciousness watches that nothing obstructs in generation of this act; that is, consciousness is indirectly participating in the process, thus it has to be informed when the urge arises, which takes place at time W. Consciousness (contextual intention) willed this act and in that sense planned it, but it did not will it to happen from the onset at that precise time. Time W is thus not the time when the subject wanted to flex the finger, but the act willed vaguely by the subject is reported by subconsciousness. Thus, consciousness is both triggering the act and also, as postulated by Libet, can veto it.[7]

In Libet's view, because consciousness can only veto decisions made by the unconscious and has little to say in initiating intentions, proscriptions alone make moral and religious sense such as "most of the Ten Commandments [which] are injunctions not to act in certain ways" ([1], 539). On the other hand, those religious systems are unrealistic which "castigate individuals for simply having a mental intention or impulse to do something unacceptable, even when this is not acted out." This is an implicit criticism of the impracticality of Christian rules, a criticism made explicitly by Kaufmann to whom Libet makes reference.[8] However, the Mosaic Law, including

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[6] The amount of information consciousness can process depends on the task: for silent reading it is 45, for typing 16, for counting 3 bits/sec ([16], 1500; [17], 203).

[7] Cf. Richard Jung's remark that Libet's result may be explained "by the small information capacity of conscious introspection and of recall during the combined observation of the clock and the intention to move" ([1], 545).

[8] "Anyone who tried to live up to Jesus' rules would become an insufferable nuisance"; "Christianity has failed morally not because Christians have not been Christian enough, but because of the very nature of Christianity" ([18], 225, 250).

the Ten Commandments, is an expression of what is most important and is included in the *Shema*, written on the *mezuzah*, and contained in the *tefillin*, namely, an injunction to feel in a certain way: love your God with all your heart, etc. To be sure, one can interpret this command to love God and a sequence of proscriptions included among the Ten Commandments. However, consider A hating B and wishing at all times to do something evil to B but always curbing his impulse. Would it be considered an expression of love of God? Body language and some subtle voice cues would sooner or later betray A's hatred of B. Would B feel comfortable around A even knowing that he can be safe? Would he consider A as someone who loves God? Needless to say, it is a rhetorical question.

A human being is not two beings next to each other and fighting one with another: the conscious and the unconscious. The two are two sides of one and the same person; thus, hidden thoughts brought to surface are an expression of one and the same personality although the personality may not be known to the person himself. Therefore, a religious system that "castigates individuals for simply having a mental intention or impulse to do something unacceptable" requires restoration of the whole person, including the unconscious so that there will be no room for unacceptable impulses. Whether such an overhaul of a human person is possible is another issue. Psychoanalysis uses various types of therapies to accomplish such a unity. Religious systems, however, being what they are, religious in respect to their statements, treat seriously the reality of God who can help humans to reach that goal. But thereby we leave the province of science.

Referring to Libet's findings, another neurologist states that "we are what we do rather than what we think, fantasise, or otherwise inwardly experience about ourselves" and the Delphic and Socratic maxim, "know thyself," is misguided and we should settle on Kierkegaard's dictum, "choose thyself" ([19], 49-50). First, it seems that one can choose himself correctly if an adequate knowledge of the self is obtained. Also, what we think, fantasise, etc. should not be set in opposition to our actions. The unity of the person, of the self, is obtained if there is a harmony between consciousness and the unconscious. The unconscious executes efficiently commands of consciousness. It may sometimes go awry, but this should not be the rule. If it is, schizophrenia ensues. Therefore, consciousness should be both the triggering and vetoing subject of each action considered conscious. We act in a certain way because we are a certain type of person, and this character of our personality is manifested in our thoughts and fantasies on the one hand, and our actions and behaviour on the other. Our inner life and our actions are two sides of the same coin, which is our own self. Our actions matter as a reflection of the self and so do our thoughts.

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