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Conscious Intention and Brain Activity

Abstract: *The problem of free will lies at the heart of modern scientific studies of consciousness. An influential series of experiments by Libet has suggested that conscious intentions arise as a result of brain activity. This contrasts with traditional concepts of free will, in which the mind controls the body. A more recent study by Haggard and Eimer has further examined the relation between intention and brain processes, concluding that conscious awareness of intention is linked to the choice or selection of a* ***specific*** *action, and not to the earliest initiation of action processes. The exchange of views in this paper further explores the relation between conscious intention and brain activity.*

I: Introduction

Voluntary action is fundamental to human existence. Most of us navigate through our daily lives with the belief that we have conscious free will: that is, we have conscious intentions to perform specific acts, and those intentions can drive our bodily actions, thus producing a desired change in the external world. The doctrine of conscious free will seems, at first sight, to be strongly dualist, and therefore incompatible with the reductionism of modern brain science: how can a mental state (my conscious intention) initiate the neural events in the motor areas of the brain that lead to my body movement? Modern neuroscience would reverse these causal roles, and would describe conscious intention as a consequence or correlate of neural preparation of action. Despite these scientific worries, the concept of conscious free will remains deeply rooted in our individual lives and in our societies. As Hume (1739/1955) observed:

> On this is founded our belief in witnesses, our credit in history, and indeed in all kinds of moral evidence, and almost the whole conduct of life (p. 182).

Perhaps the most interesting scientific attempt to break out of this impasse comes from the experiment of Libet *et al.* (1983). Before describing the experiment in detail, I [PH] would like to single out two reasons why I believe it has been so

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important. Libet was the first to attempt a scientific psychophysiology of free will. His experiment brought scientific method to a question that had previously been purely philosophical. Using this method, he produced data that support the traditional neuroscience view, and deeply undermine the concept of conscious free will: preparatory brain activity causes our conscious intentions. The second outstanding feature of Libet's study is the insight that we may have a conscious veto over the acts our brain has previously unconsciously prepared (so called 'free won't'), even if we lack conscious free will. This brilliant revision of the traditional concept of free will saves most of its desirable corollaries, such as individual liberty and moral responsibility, while maintaining compatibility with modern neuroscience. I will next briefly summarise the experiment which brought Libet to these conclusions, and will then introduce the controversy over selection.

Libet and colleagues asked subjects to fixate a small clock hand, which rotated once every 2.56 s. Subjects then made a voluntary movement (they were instructed to flex their wrist 'freely and capriciously') at a time which they themselves chose. The clock continued to rotate for a random interval after the voluntary movement, and then stopped. Subjects then reported the position of the clock at which they first became aware of the will to move. Libet termed this the 'W judgement', and took it as the first moment of conscious intention. In other conditions, subjects judged the time at which the actual movement began ('M judgement'): for the present discussion the W judgement is the most important, though we shall return to the M judgement later.

The exact moment at which the action began was calculated by measuring the electrical activity in the muscles involved. The preparatory activity in the motor areas of the brain (the readiness potential — RP) was also calculated by measuring electrical activity with a scalp electrode placed over the motor cortex, and averaging epochs of data prior to each voluntary action. The RP is a well-established gradual increase in electrical activity in the motor cortical regions, which characteristically precedes willed actions by 1 s or more, and is strongly related to the effort, thought and attention required to generate the action (Kornhuber and Deecke, 1965).

The combination of psychophysical estimates and physiological recording gave Libet and colleagues the measures required to address the question of conscious free will. Specifically, the temporal order of the two measures allowed Libet and colleagues to investigate which event was cause and which was the effect. If the moment of conscious intention preceded the onset of the readiness potential, then the concept of conscious free will would be tenable: the early conscious mental state could initiate the subsequent neural preparation of movement. But if the moment of conscious intention followed the onset of the readiness potential, then conscious free will cannot exist: a conscious mental state must be a consequence of brain activity, rather than the cause of it.

Libet *et al.*'s data showed the latter pattern. Their results can be stated quite simply, and are shown schematically in Figure 1. The readiness potential began around 1000–500 ms before the onset of actual body movement. The exact time

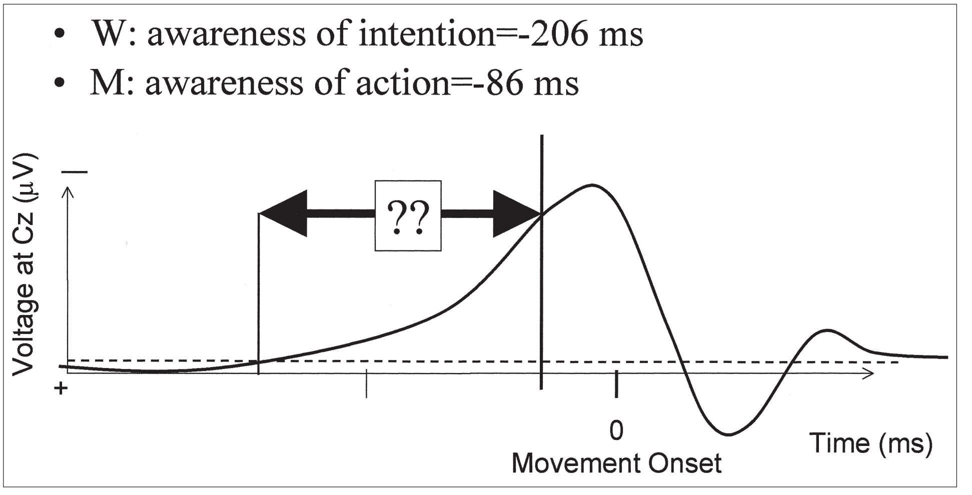

Figure 1. Schematic showing the important features of the results of Libet *et al.* (1983).

of onset differed between two different types of RP observed in the data, which Libet called RPI and RPII. Type I RPs had earlier onsets than type II RPs. Type I RPs were found in blocks where subjects reported the experience of planning and consciously preparing their actions, on at least some trials. Type II RPs were found in blocks where subjects reported that their actions were unplanned, and that they occurred more spontaneously.

The key result for the present purpose, however, is the interval between RP onset and W judgement. Subjects' W judgements showed that they only experienced conscious intention an average 206 ms before movement onset. This is around 350 ms after the onset of type II RPs, and around 500 ms after the onset of type I RPs. Thus, the brain is preparing the purportedly 'free' action significantly before the subject himself is aware they he intends to move. This temporal gap poses a difficulty for the traditional concept of free will.

Several critiques of the above experiment were published in 1985, in response to a target article in *Behavioral and Brain Sciences* (Libet, 1985). These critiques raise a number of problems with Libet's method, but only one of these really concerns us here. People are generally poor at judging the synchrony of two events occurring in different perceptual modalities (Sternberg and Knoll, 1973) or perceptual streams. In particular, events in an attended stream appear to occur earlier than simultaneous events in an unattended stream (the so-called Prior Entry phenomenon). Since Libet's subjects presumably divided their attention in varying proportions between the external clock and their own internal states in order to make the W judgement, the precise numerical value of 206 ms must be treated with caution. In my own view, criticisms of the Libet method based on attentional biases have been overstated. Estimates of the prior entry effect run from 70 ms (Sternberg and Knoll, 1973) down to 12 ms (Shore *et al.*, 2001; Haggard and Johnson, 2001). Even the largest of these values is an order of magnitude smaller than Libet's gap between readiness potential and W judgement.

II: Specificity and Intentions

Our own point of entry to the debate was twofold (Haggard and Eimer, 1999). Firstly, we wanted to investigate the causal relations between brain preparation and conscious awareness in more detail. Second, we wanted to link the two types of event by an inference that did not depend on the absolute numerical value of a timing judgement (which henceforth I shall call a 'Libet estimate'). Our experiment included some other factors, such as a comparison between fixed-choice and free-choice action, which are not of interest here.

The original 1983 paper suggested that the readiness potential was the cause of subsequent conscious awareness: as the subtitle put it: 'The unconscious initation of a freely voluntary act'. The basis for this causal argument was the temporal precedence of readiness potential (RP) onset over conscious intention, as described above. Temporal precedence may be important for the controversy between mind-to-brain vs brain-to-mind causation, but it is a necessary rather than a sufficient condition for a causal relation. In particular, there might well be other neural premotor events that are more plausible than the RP as causes of conscious intention. We particularly wished to investigate which of the readiness potential or the lateralised readiness potential (LRP) is a more plausible cause of conscious intention. Therefore, we now briefly explain the meaning and importance of the LRP.

The early portions of the RP are symmetrical over both hemispheres, but the later portions of the RP show an increasing shift towards the hemisphere contralateral to the hand that will make the forthcoming action, typically beginning some 500 ms prior to movement onset. This Lateralised Readiness Potential (LRP) can be calculated by subtraction of electrode signals located symmetrically over the two motor areas (Eimer, 1998). The LRP has a particular psychological significance in situations where the subject must choose between a left- and a right-handed action: once the LRP has begun, the selection of which action to make must be complete. That is, by LRP onset the intention has progressed from abstract stage ('Do something or other!') to drive a specific movement ('Do precisely this!').

Comparing the plausibility of two candidate causes often comes down to comparing how well each candidate correlates with the putative effect (Mill's method of concomitant variation). We relied on the fact that these experiments always involve collecting large numbers of repeated trials. The variability across trials in both W judgements and RPs is typically high. Therefore, we related both RP and LRP onsets to W judgements. For example, if the RP is truly the cause of conscious intentions, then trials which happen to have early RP onsets (i.e., onsets occurring long before the movement itself) should also have early conscious intentions. Ideally, this would be done by predicting W judgement value from the RP or LRP onset value in each trial. However, the RP and LRP measures have a poor signal-to-noise ratio, and can only be obtained by averaging across several trials. Therefore, we were obliged to apply Mill's logic backwards: we classified each subject's trials according to whether the W judgement was early or late relative to that subject's median W value, and calculated RPs and LRPs corresponding to these early and late judgements respectively.

Briefly, we found RP onset did not covary with W judgements: trials with early W judgements in fact showed later RP onsets than trials with late judgements. LRP onset, however, did covary with W judgement: trials with earlier W judgements had earlier LRP onsets than trials with later W judgements. The pattern of results is shown in Table 1. From these data we concluded that the RP could not be the cause of conscious intention, but the LRP could be a possible cause of conscious intention. Since the motor system must have selected which specific movement to perform by the time that the readiness potential lateralises, we concluded that conscious intentions were related to specific rather than general preparation for action.

	Early W trials	Late W trials
Mean W	–530	–179
LRP onset	–906	–713

Table 1. Mean LRP onset times and mean W (awareness of intention) judgements for trials showing early and late W. Data from Haggard and Eimer (1999).

III: Implications

The purpose of this paper is to discuss the implications of both the original result, and of our re-enactment for the cognitive neuroscience of willed action. Libet's original result suggested that conscious intentions were a consequence of the very early general preparation for movement by the brain. Our result, in contrast, suggests that conscious awareness of intention should be attributed only at a later stage in the genesis of an action: namely after the selection of a specific motor implementation of the action by a left or right handed keypress.

The question of what causes conscious intentions is important for several reasons: hence this discussion. First, we need to know what brain event, if any, causes conscious intentions, in order to shed light on the traditional problem of conscious free will. Second, identifying the neural basis of intentions may prove useful in understanding disorders of intentional action such as those which occur in schizophrenic patients with hallucination and delusions.

In this section, I will discuss several implications of the specificity result of Haggard and Eimer (1999) described above. I believe the result has implications for the evolutionary value of action awareness, for the traditional free will problem, and for the unity of conscious awareness. Finally, and more speculatively, I think the specificity result may have implications for Libet's salvaging of free will through the conscious veto. These will be discussed in turn.

1. Does conscious awareness arise at the stage of specification?

Why might conscious awareness arise at the stage where the CNS selects the specific movement which will be used to achieve the action? Computational approaches to motor control have generally agreed that movement selection is the most informationally difficult problem in action. In most everyday actions, there are several different ways to achieve a desired goal. For example, I could reach for the milk bottle with my left or my right hand, I could take a couple of steps to get closer to the fridge, or I could extend my arm to the limit of its reach: in each case I succeed in the action of getting the bottle, though I do so using very different movements. The CNS faces the problem of choosing just one of the infinite set of possible movements. This problem is ill-posed: there is no unique solution. This is known in psychology as the problem of motor equivalence (Hebb, 1949), and as kinematic redundancy in the specific case of computational motor control (Wolpert and Ghahramani, 2000). The limited action repertoire of so-called 'intelligent' robots suggests that the human motor system uses quite sophisticated information-processing to solve the problem. Our specificity result suggests that conscious awareness may be a consequence of this information-processing. Awareness of what we will do is tied to the selection of specifically how we will do it. Other accounts of consciousness, based on very different domains, have suggested that conscious awareness arises when particular kinds of computational processes occur (Jack and Shallice, in press). Our specificity result similarly suggests that consciousness of intention may be related to a particular kind of processing involved in movement selection.

This view makes clear predictions which could be tested in subsequent research. The phenomenology of intention should be strongest when the movement selection computations are most intensive. For example, awareness of intention may be more vivid, and may possibly occur earlier for actions where the subject must carefully select between a large number of alternative movements, for example when reaching for one object among a number of distractors.

2. Specificity and the free will problem

Our result used a correlational approach, based on Mills' method of concomitant variation, to identify the cause of conscious awareness of intention. Famously, however, correlation is not causation. In particular, a correlation between two events does not identify which is the cause and which is the effect. In our result, the only grounds for inferring that the LRP causes awareness of intention, rather than the other way around, is the temporal precedence argument originally used by Libet: causes precede their effects. Temporal precedence is particularly germane here, because, as described above, the numerical values of Libet estimates are not a robust guide to the exact times of mental events. Biases in cross-modal synchronisation, prior entry, and individual differences in time perception could all make Libet estimates poor guides to the actual time at which subjects experience an awareness of when they will act (for the sake of this discussion, we will grant the assumption that such a distinct mental event occurs in the first place).

Anyone wishing to rescue the traditional concept of conscious free will should pay close attention to these methodological issues. Libet's basis for rejecting the traditional concept of free will as the initiator of action was the long gap between RP onset and W awareness (see Figure 1). It is this gap, or temporal precedence, that justifies a brain–mind rather than a mind–brain direction of causation. We have now suggested that LRP, rather than RP onset is the physiological event of interest, and LRP onset of course occurs much later than RP onset. Therefore, the gap between brain and mind events that needs to be explained away by the proponent of conscious free will is much narrower judging from our result than Libet originally reported. Inspection of Table 1 shows that if numerical W estimates can be shown to be delayed by, say 500 ms, relative to the actual conscious experience of intention, then the temporal precedence of LRP over W awareness would be reversed. The free will theorist could suggest that conscious intentions cause the brain processes of movement selection (of course, the other arguments against such a view would not thereby be answered).

I doubt that quirks of human estimation, such as the prior entry effect, could by themselves produce errors of as much as 500 ms in estimation. But there may be other reasons why reports of conscious experience are delayed relative to the actual experience itself. For example, the P-centre phenomenon originally discovered for speech stimuli (Morton *et al.*, 1976) may apply equally to internal events. The P-centre phenomenon refers to the fact that the perceived onset of a speech stimulus lags its physical onset, and seems to be attracted by the 'centre' of the stimulus. Intentions might likewise be extended in time. The requirement to judge their onset as a discrete event is clearly somewhat arbitrary and difficult: people may resort to judging the centre of some extended process. The earliest stages of that process could perhaps precede LRP onset.

Again, it is useful to think of empirical approaches to the question of temporal precedence. An experiment identifying a neural event occurring at the precise moment of conscious awareness could be particularly important. For example, locking EEG records with respect to W judgements on each trial, as opposed to locking them to movement onset, might reveal a particular neural event, let us call it W_n, which occurs close to the time of W. If W_n were found to follow both RP and LRP onset, and also to covary in time with them, then I believe this would be strong evidence for brain-mind causation, rather than the mind-brain causation hypothesised by conscious free will accounts.

A second possibility for identifying the precise temporal relations between brain activity and awareness of intention is suggested by a fascinating but little-known study performed by Fried *et al.* (1991). Those authors stimulated the frontal cortex intracranially, through surface electrodes implanted as part of a surgical procedure for intractable epilepsy. Stimulation at some of their more anterior electrode sites, corresponding to Brodmann's area 6, caused their patient's to report an urge to move a specific body part, or a feeling that they were about to move. Weak stimulation typically evoked such reports of conscious intention, while stronger stimulation evoked actual movements of the same body part. The similarity of these reports to the W judgement is interesting, though of course

Fried's subjects' reports were not reports of the time of awareness. Moreover, brain processes induced by experimental stimulation and the spontaneous brain processes that are measured with EEG may be quite different. Nevertheless, it is tempting to think that Fried's patients experienced passively what Libet's and our subjects achieved themselves. Fried's result is clearly consistent with a brain–mind direction of causation: conscious awareness of intention is the consequence of frontal brain activity.

Unfortunately, the Fried *et al.* study was not chronometric: we have no clear idea of the interval between electrical stimulation and the subject first feeling an urge to move. A replication of the Fried study, in which subjects made rapid choice responses to their own awareness of intention would be very interesting scientifically. It would also provide timing estimates which did not rely on the Libet clock, and would therefore avoid the problems of cross-modal synchronisation, prior entry, etc.

3. Specificity and the relation between Libet's W and M

A useful framework for thinking about voluntary action and conscious awareness is given in Figure 2. The left hand side shows the brain events occurring with voluntary action, while the right hand side shows the conscious experiences that may be associated with voluntary action. I wish to make the strong claim that the relations between the neural events and conscious events are not one-to-one, but are many-to-many. Libet *et al.*'s (1983) paper was the first to attempt a psychophysiology of free will. It made a link between neural preparation and

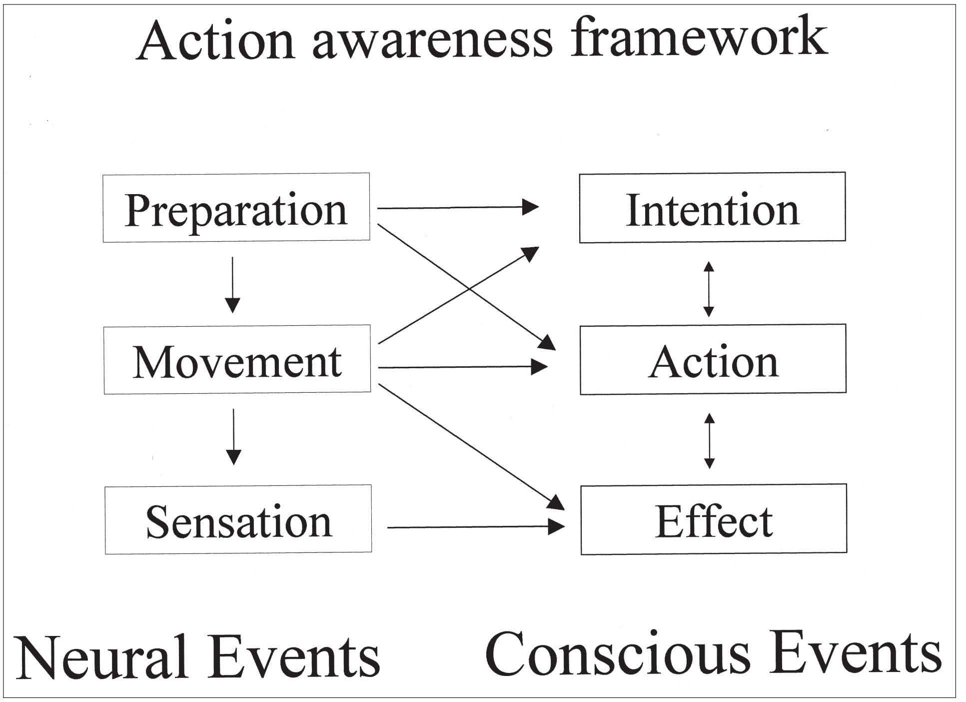

Figure 2. A framework for understanding the conscious awareness of action. See text for details.

awareness of intention. Our specificity result suggests that awareness of intention depends also on the actual movement made, giving a many-to-one mapping from neural events to conscious events. Other studies (Haggard and Magno, 1999) have suggested that judgements of when we actually move (Libet's 'M judgement') depend on the plan or intention to move, as well as on actual muscular contraction. This implies a one-to-many mapping, whereby neural preparation contributes to awareness of both intention and action. In more recent work (Haggard *et al.*, in press), we have reported a binding effect in operant action, whereby the conjunction of intentional actions and their effects leads to these events being perceived closer together in time than the same events presented singly. In this sense, all the neural events on the left hand side of Figure 2 seem to contribute to any conscious event studied. That is, conscious experiences surrounding action are integrated from a series of actual events.

I believe this integrative operation of action awareness explains an interesting feature of Libet's original data. In the 1983 paper, Libet focussed on explaining the gap between RP onset and W. However, I believe his data reveals a second gap which is equally intriguing for students of consciousness. In Libet's data, the interval between the neural events of preparation (RP onset) and actual movement is probably around 1 s (Libet's criteria for detecting RP onset were rightly conservative, so his reported measures are around 500–900 ms, depending on whether an RP is type I or type II). Interestingly, the equivalent interval between the corresponding conscious events W and M, is much shorter (Figure 3). Thus, an extended period of neural activity produces a much narrower, more discrete conscious awareness. This again suggests an integrative operation of conscious awareness, which we shall call intentional binding elsewhere (Haggard *et al.*, in

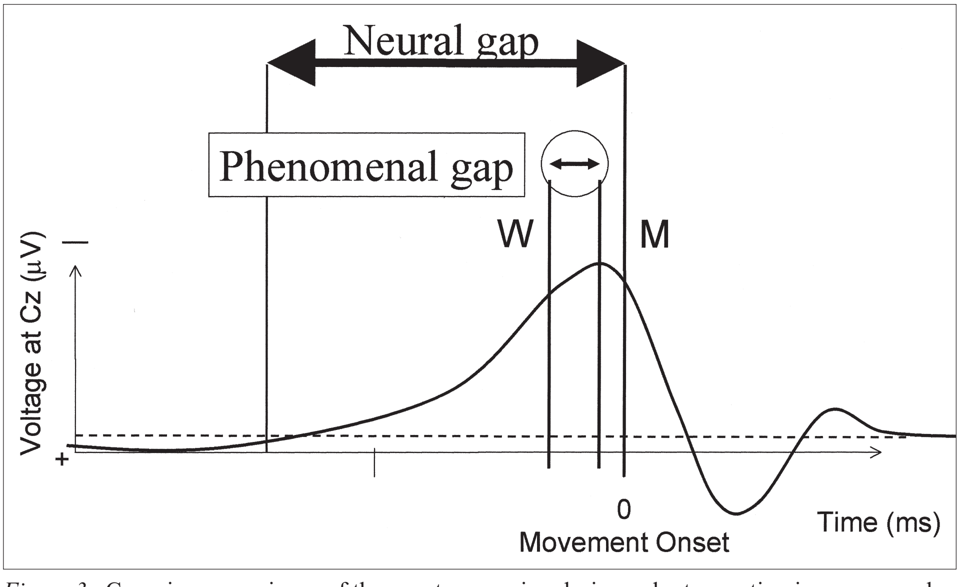

Figure 3. Conscious experience of the events occurring during voluntary action is compressed in time relative to the actual occurrence of those events. Note that the neural gap between RP onset and movement onset is experienced as a much shorter interval between W and M.

press). It seems likely that this integration has the function of producing unified experience of our own voluntary action across space and time, though we must be somewhat careful about this claim because Libet judgements do not test the unity of experience directly.

If I am right about the integrative operation of action awareness, then the specificity result also makes sense. Asking a subject to make M or W judgements does not guarantee that they have a distinct underlying conscious experience corresponding to those judgement categories. Rather, people may have conscious awareness of a compressed core of events clustered around the action itself. Movement specification lies closer to that core than the earliest onset of the neural activity.

4. Specificity and the conscious veto

Having disproved the traditional concept of free will, Libet salvaged some of its important consequences such as attribution of actions to agents, free choice and personal responsibility. He did this by noting that, while actions appear not to be freely initiated, they may be freely stopped. He suggested that there was sufficient time between W awareness and movement onset for a conscious veto to operate.

I suggest there may be a similarity between conscious veto and the relation between W and movement specification. In a choice situation like our experiment, W awareness seems to be related to modification of action. One reason for tying W awareness to specification could be to allow an option for final, conscious decision on the question 'Is that really the right way to achieve what I intend to do?' Libet's conscious veto has a similar but more radical role of asking whether the action should be cancelled entirely. That is, Libet's veto corresponds to the internal question 'Do I really want to realize this intention?' It seems to me that the two questions should be related: once an intention has be translated to a specific action plan, and has reached conscious awareness, a whole series of checks and internal mental simulations should begin at many levels in the motor system. These checks would monitor both the desirability of the action and its effect (Libet's veto), and also whether the specific action plan is the best way to achieve the effect (Haggard's specificity). It is unclear which monitoring processes reach conscious awareness, and under what circumstances. The philosophical implications of this multiplicity of monitoring processes also remain to be worked out.

IV: Libet's Position

Haggard and Eimer (1999) have produced a fine experimental paper to investigate further the issue of how the time of conscious will (W) is related to the onset of brain activity in a voluntary act. Their findings confirm those of Libet *et al.* (1983), in that onset of the readiness potential (RP) precedes the appearance of W by a substantial time. This sequence was found by them also when lateral readiness potential (LRP) was recorded.

The onsets of the those LRPs associated with the group of earlier reported Ws were significantly earlier than those associated with the group of later Ws. However, their vertex recorded RPs did not exhibit such a covariance with early vs. later Ws. That led Haggard and Eimer to conclude that the vertex RP does not represent a *causal* process in volitional events and that the LRP (recorded over pre-motor cortex) does appear to represent a causal factor in the appearance of W.

This analysis by Haggard is a well reasoned position on the issue of where, in the brain, the conscious will (W) leading to a voluntary act, arises. However, their

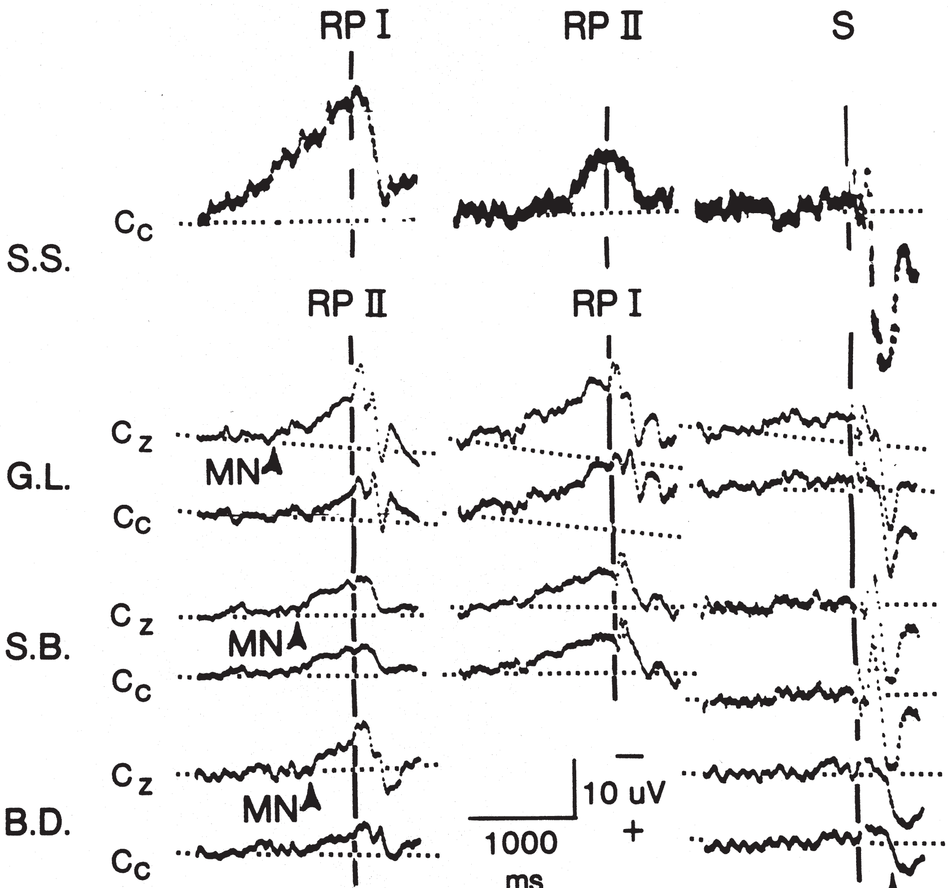

Figure 4. Self-initiated RPs

Each horizontal tracing gives potentials averaged for 40 trials. For each subject, C_z is recorded at the vertex; C_c electrode is over the premotor area, contralateral to the side of the movement. (This location is similar to location for LRP of Haggard & Eimer.) The solid vertical line through each column represents 0 time, given by the EMG recorded over the suddenly activated muscle, or by the skin stimulus trigger (in Column S). Type II RPs are with no reports of preplanning; Type I RPs are for trials in which subject reported pre-plannings of when to act. Column S shows ERPs (event-related-potentials) recorded with skin stimuli delivered at random times not known to the subject. (The large surface-positive potential following the stimulus is the P_{300} component, characteristic in tasks which contain uncertain conditions). (From Libet *et al.*, 1982).

analysis and conclusion depends on an acceptance of their data as unambivalent and of the assumptions that underlie their analysis. and[BL] shall now discuss that problem.

Technical differences between our experiments

In the experiments of Libet *et al.* (1982) an important difference was found between voluntary acts that involved some degree of 'pre-planning' (as reported by the subject) and those acts that arose fully spontaneously. That difference was associated with a difference between the respective RPs. When subjects reported some pre-planning, of when to perform the act, the RP ('RPI') had a distinctly earlier onset and was larger in amplitude than the RP ('RPII') without such pre-plannings. Onset for RPI averaged –1053 msec (SD 173), while RPII onsets averaged –577 msec (SD 151) (Libet *et al.*, 1982). Additionally, onsets of RPII were more abrupt, while those for RPI were not (see Figure 4).

In the experiments in which W was also measured (Libet *et al.*, 1983) onsets of RPI averaged –1025 msec (or –784 msec when onset was measured where 90% of the area under RP began). Onsets of RPII in these experiments averaged –535 msec (or –527 msec for 90% of the RP area). Mean value of W was close to –200 msec for all series (actually –204 msec.), with RPI trials W averaged –233 msec; with RPII trials W averaged –192 msec. Haggard refers to these W reports as 'Libet's estimate' of the actual timing of the conscious will. But our W's were the subjects' own direct reports. They were not based on any theoretical estimates.

It is noteworthy that W values were closely similar for both RPI and RPII trials, even though the RP onset times were strikingly different for the two conditions. That provided part of the evidence for the view that the decision 'to act now' is a common process for voluntary *acts*, even when pre-planning or deliberation about choices has preceded this final phase.

The RPs recorded by Haggard and Eimer have a much earlier onset and much larger amplitude than even our RPI tracing (those associated with reports of pre-planning by the subjects). That suggests that the RP early onsets and large amplitudes found by Haggard and Eimer also reflect pre-planning by their subjects.

Of course, the features of Haggard and Eimer's RPs do not in themselves prove that pre-planning was behind them, as they did not query their subjects about such experiences. However, the nature of the instructions to their subjects certainly supports the pre-planning view. Their subjects were asked to perform in two different modes:

(1) In the 'fixed' movements subjects were to move always the same hand; in a series of 40 trials they did 20 with the left hand and 20 with the right. In the 'free movement' mode subjects were to decide (on their own will) which hand to use for a given movement.

(2) In addition, subjects were encouraged to produce roughly equal numbers of left and right choices, and to avoid any patterns of sequences in succeeding trials! With such instructions the subjects would clearly have to do some pre-planning about each movement, to meet the specifications involved.

In our study we placed the greater significance on our RPII results, with no reported pre-plannings, for the relation to the values of W (reported time of first awareness of a wish or urge). Onsets of RPIIs averaged –535 msec, and were distinctly later than those for RPIs, and much later than the RPs recorded by Haggard and Eimer. Indeed, onsets of our *RPIIs* were not much different from the onsets of *LRPs* recorded by Haggard and Eimer! The fact that our W values were similar for both RPIs and RPIIs suggested that the significant cerebral processes leading to the appearance of W are represented by RPIIs (free of pre-plannings) rather than by RPIs (with pre-plannings).

If the RPs recorded by Haggard and Eimer are contaminated by a large component due to pre-planning, that would make their usefulness in a role for causing the appearance of W open to serious question.

The onsets of RPs and LRPs for early vs. late Ws

To gain further insight into which cerebral processes may have a causal relationship to the appearance of W (conscious will), Haggard and Eimer carried out an ingenious analysis of their data. They selected out the Ws with earlier values and the Ws with later values. These values formed two distinct groups of Ws, an earlier one with a mean value of –906 ms (SE 85ms) and one with a mean value of –713 (SE 106 ms). They then compared RP and LRP onset values for these two groups of Ws, early vs. late.

First, there are some potential difficulties with their data, as determined for this purpose. Both of their W groups had mean values distinctly larger than our Ws (–233 ms or –192 ms). A possible reason for this difference from our W values may lie in their instruction to the subjects. Their subjects were asked to report the clock time 'at which they first began to prepare the movement'. In the study of Libet *et al.* (1983) subjects were asked to note the clock time at which they 'were first aware of wanting to move'. The instruction for W in Haggard and Eimer's study would appear to be more related to having a conscious experience of preplanning when to move, rather than to an awareness of the will or wish to move. That would explain their much earlier W values than in our study. But it also suggests that their W values were not actually indicators of the time for appearance of conscious will to 'act now'. Determinations of early vs. late values for our kind of W could conceivably yield a different relation to onsets of RP and LRPs than the one found by Haggard and Eimer.

Secondly, there is also a question about the RP onset values that were used in Haggard and Eimer's analysis relative to their early vs. late Ws. Onsets of their RPs were not only very early but also rather indeterminate. Haggard therefore settled on an attempt to calculate an onset during the –1000 to –500 msec interval in the ongoing RP. That was the time period more related to the RPs studied by Libet *et al.* However, Haggard and Eimer did not measure an actual onset time, as the RP had already begun much earlier. Instead, they measured the mean amplitude during the –1000 to –500 ms interval. This value was –4.630 V for early awareness (W) trials and –5.614 V for late Ws. These values did not differ significantly (P = 0.319). As they regarded the amplitudes to be indicators of relative onsets, they concluded that their RP onsets do not covary with the early vs. later W times. They admitted that if the baseline preceding their whole RP could have been determined, that there might have been a difference in onsets that may have covaried with W times. However, even if that were possible the actual very early onsets of their RP would, in my opinion, not be relevant to the timing of Ws directly related to the final 'act now' phase of the voluntary act (see above).

The use of *mean amplitude*, as the indicator of an *onset time* for an RP phase during the –1000 to –500 interval, seems highly questionable. No evidence is offered to justify the validity of that procedure. In addition, they observed that the RPs associated with early Ws had a somewhat lower amplitude than those with late Ws. This difference in amplitude was already visible at about –2000 ms, well before the –1000 to –500 ms interval. That difference in RP amplitude is interesting. But since it begins at about –2000 ms it is difficult to see why the amplitude during the –1000 to –500 ms interval should suddenly become an indication of onset of an RP phase. I have to conclude that their calculated onsets for RPs relative to early vs. late Ws do not prove their major point: that RP onsets do not covary with W times while LRP onsets do vary.

Even the onsets assigned to their LRPs are calculated by a method designed to reduce baseline noise and make onset times clearer. I do not question the probable validity of such a method. However, it is noteworthy that a straight forward visual inspection of their LRP grand means (Fig. 4 in Haggard and Eimer, 1999) does not show a convincing difference in the LRP onsets for early vs. late Ws.

General discussion

Haggard proposed that Libet's RP results suggested a very early preparation for movement. The fact is, that our RPII values (onset mean at –535 ms) are actually lower (i.e. later) than the onset times of the LRPs in Haggard's work (–795, or –895 ms). That does not support Haggard's suggestion that conscious awareness of intention arises at a much later stage relative to our RP process.

Haggard's view that that awareness (W) arises after the specific motor implementation of the action is reached, as reflected in the LRP, may or may not be valid. In Libet's study, the specificity of the action was already determined for all the acts, by the general instruction before all the trials. That makes it difficult to sort out the locus and timing of the specificity in relation to Libet's RPs. Haggard's suggestion, for studies in which subjects would choose and select between a number of alternative movements, would indeed be interesting and informative. However, simpler studies, with a constant and predetermined choice, would seem to provide a clearer answer to the *timing* of the conscious intention to move.

In Libet's study the temporal gap between onset of RPII and W was about 350 ms. That indicated that a brain process *initiated* the voluntary process well before subjects were aware of the wish/intention to act. Haggard indicates that this gap is much narrower in their results, relating onsets of LRPs to their Ws, 6 and –534 msec respectively. But the actual values in their work are LRP onsets at –906 ms vs. –530 ms for early Ws; and LRP onsets at –713 ms vs. –179 ms for late Ws (see

Haggard's Table 1, above). These gaps are hardly narrower than the –350 ms in Libet's study.

Haggard speculates, that *if* W reports can be shown to be delayed by 500 msec relative to actual conscious intention (something that is untestable), the gap between LRP and actual awareness would be reversed. But even a 500 msec error in W would not place it ahead of LRP onsets of –906 and –713 msec.

It is Haggard's contention that the RP cannot have a causal relation to the appearance of conscious will (W), because its onset does not covary with early vs. late Ws. The validity of this finding was shown to be highly questionable, see above. As I noted above, the RP that is more relevant to the final initiation of the voluntary process was our RPII, recorded with freely spontaneous acts devoid of any pre-plannings by the subjects. Until onsets of RPIIs for early vs. late Ws are determined, *one cannot conclude* that the relevant RPs do not covary with early vs. late Ws and are not causal to W.

The important issue of free will is related to all such studies of volition. Libet noted that although free will does not appear to initiate a voluntary process it could still act as a *control* agent. It could allow the unconsciously initiated process to go to completion, or veto it and prevent the actual act from occurring. A full treatment by Libet of free will appeared in the August/September 1999 issue of the *Journal of Consciousness Studies*. Haggard wants to alter the veto view to one of 'modification', rather than a conscious veto in the true sense. But his introduction of questions to be decided upon consciously by the subject is really speculative. Our subjects never reported having the kinds of experiences in relation to their veto that are suggested by Haggard.

Haggard has made a meaningful and important experimental entry into the issue of brain and conscious voluntary acts. But, in my view, his findings thus far need to be addressed on some important technical grounds before his conclusions can be regarded as valid.

V: Conclusion

This exchange has highlighted for me [PH] two outstanding issues, which any future neuroscience of free will should address. The first issue is largely philosophical, and amounts to what is chosen in voluntary action. While will (generation of action) and choice (selection of action) are conceptually distinct, this exchange has reminded me that neuroscientists often handle them together. The philosophical concept of willing implies a single event, a single moment in time, where the mind initiates the brain and body processes which culminate in action. The neuroscience concept that both Libet and I work with is of a continuous set of neural and informational processes, extending over at least 500 ms and often much more, in which the action is developed, elaborated and specified by the brain. Libet's approach seems to be to identify a moment of willing, and a moment of conscious awareness, and to draw inferences from the time gap between them. My own approach has focussed more on the hierarchical series of choices that culminate in voluntary actions, rather than on the moment of initiation or willing which begins that series of choices. But perhaps choice is as important as will in understanding the conscious experience of action. Two examples of choice are the specification of how the action is to be translated into movement (Haggard and Eimer, 1999), and the choice to continue or to cancel an action whose brain preparation is already underway (Libet's veto). I believe that this exchange has clarified the relation between consciousness and choice, but the traditional question of the relation between consciousness and willing requires further work. Conceptual analysis could help here: do the processes of willing and selection (choice) differ qualitatively? Is willing merely the first of a series of choices, namely the choice to begin the process of action rather than not to begin it? Should consciousness of willing differ in any significant way from consciousness of selection? What informational features of action choice influence the conscious awareness of the action chosen?

A second message I have drawn from this exchange is the problem of describing and classifying the brain process of action initiation. The crux of this problem is that existing classifications are post hoc. We can find a difference in readiness potentials in our data, and we can then look for an explanation of it, but we cannot intervene on the processes of action initiation and see how RPs and conscious experience are altered in consequence. Much of Libet's position hinges on the distinction between Type I and Type II Readiness Potentials. Even more hinges on the technical questions of how best to detect RP onsets. While the distinction between the two types in his data is very clear, it is less clear what critical difference in mental activity leads to these different classes of brain activity. Classifying and describing the elements of neural preparation for action is a prerequisite for the project of correlating brain activity with conscious experience. A future neuroscience of free will should require systematic and parametric studies in which different patterns of brain processes are distinguished, and related to actions that result, and to subjective reports. Experiments such as that of Fried *et al.* (1991) in which the neural preparation of action can be controlled, albeit artificially, seem to offer one of the few possible chances of achieving this. Safe and non-invasive intervention on the neural processes of initiation of voluntary action using Transcranial Magnetic Stimulation (TMS) remains a major research goal of any future neuroscience of free will.

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