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TIME OF CONSCIOUS INTENTION TO ACT IN RELATION TO ONSET OF CEREBRAL ACTIVITY (READINESS-POTENTIAL)

THE UNCONSCIOUS INITIATION OF A FREELY VOLUNTARY ACT

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SUMMARY

The recordable cerebral activity (readiness-potential, RP) that precedes a freely voluntary, fully endogenous motor act was directly compared with the reportable time (W) for appearance of the subjective experience of 'wanting' or intending to act. The onset of cerebral activity clearly preceded by at least several hundred milliseconds the reported time of conscious intention to act. This relationship held even for those series (with 'type II' RPs) in which subjects reported that all of the 40 self-initiated movements in the series appeared 'spontaneously' and capriciously.

Data were obtained in at least 6 different experimental sessions with each of 5 subjects. In series with type II RPs, onset of the main negative shift in each RP preceded the corresponding mean W value by an average of about 350 ms, and by a minimum of about 150 ms. In series with type I RPs, in which an experience of preplanning occurred in some of the 40 self-initiated acts, onset of RP preceded W by an average of about 800 ms (or by 500 ms, taking onset of RP at 90 per cent of its area).

Reports of W time depended upon the subject's recall of the spatial 'clock-position' of a revolving spot at the time of his initial awareness of wanting or intending to move. Two different modes of recall produced similar values. Subjects distinguished awareness of wanting to move (W) from awareness of actually moving (M). W times were consistently and substantially negative to, in advance of, mean times reported for M and also those for S, the sensation elicited by a task-related skin stimulus delivered at irregular times that were unknown to the subject.

It is concluded that cerebral initiation of a spontaneous, freely voluntary act can begin unconsciously, that is, before there is any (at least recallable) subjective awareness that a 'decision' to act has already been initiated cerebrally. This introduces certain constraints on the potentiality for conscious initiation and control of voluntary acts.

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INTRODUCTION

The 'readiness-potential' (RP), a scalp-recorded slow negative potential shift that begins up to a second or more before a self-paced act (Kornhuber and Deecke, 1965; Gilden *et al.*, 1966), can also precede self-initiated 'freely' voluntary acts which are not only fully endogenous but even spontaneously capricious in origin (Libet *et al.*, 1982). The appearance of preparatory cerebral processes at such surprisingly long times before a freely voluntary act raises the question of whether conscious awareness of the voluntary urge or intention to act also appears with such similar advance timings. The present study attempts to answer this question experimentally.

In the present study, the experience of the time of the first awareness of the urge to move was related by the subject to his observed 'clock-position' of a spot of light revolving in a circle; the subject subsequently recalled and reported this position of the spot. Thus the experience of timing of the awareness was converted to a reportable, visually related spatial image, analogous to reading and recalling the clock-time for any experience. (The reliability and validity of this operational criterion are further considered below.) This indicator of the time of the conscious experience could then be related (1) to the actual time of the voluntary motor act, as indicated by the electromyogram (EMG) recorded from the appropriate muscle, and (2) to the time of appearance of the simultaneously recorded RP that is generated by the brain in advance of each act. The voluntary motor acts under study were those produced with minimal or no restrictions on the subject's independent choice of when to act, and under instructions that encouraged spontaneity of each volitional urge to act (Libet *et al.*, 1982).

The present findings thus provide experimental evidence on the timing of the conscious intention to act relative to the onset of cerebral activity preparatory to the act, and on the roles of conscious processes in the initiation of a freely voluntary motor act.

METHODS AND PROCEDURES

Subjects

Six right-handed college students were studied as two separate groups of three each. Group 1 comprised 3 females (S.S., C.M. and M.B.), but the quality of the EEGs and the minimal amplitude of the RPs of one precluded using much of her data. Group 2 consisted of 2 males and 1 female (S.B., B.D. and G.L.). Study of this group began a few months after completing the study of Group 1.

Recording

The d.c. recording and averaging of the EEG has been described (Libet *et al.*, 1982). For present purposes, analysis of RPs is made for those recorded at the vertex, where they were all maximal. (For the first 4 experimental sessions with Group 1, only the contralateral precentral recording site is available.) Linked mastoid electrodes served as the reference lead, with a ground electrode on the left ear lobe. Controls excluded the electro-oculogram as a source of the slow potentials. In each experimental series, 40 trials were performed and averaged by a computer of average transients (CAT 400B). The 2 s period of EEG stored by the CAT with each trial included a 1.4 s period already on the recording tape before 'O-time'. The latter was signified by the EMG, recorded with bipolar electrodes on the skin over the activated muscle of the right forearm.

Procedure

The subject sat in a partially reclining position on a lounge chair with an observer present in the room. Each trial was started only when the subject considered himself comfortably ready. The trial began with a brief 'get-ready' tone. This signalled that during the next 1-3 s the subject should relax his muscles, especially those of the head, neck and forearm, blink his eyelids if he wished, and fix his gaze on the centre of the 5 inch circular screen of a cathode ray oscilloscope (CRO) that was positioned at about 1.95 m away in his direct line of vision. At the end of these irregular get-ready periods the operator activated the PDP-12 computer to initiate circular revolution of the beam of the CRO. The CRO spot of light revolved in a clockwise circle near the circumference of the screen starting from the '12-o'clock' position; this motion simulated a sweep secondhand of a clock but each revolution was completed in 2.56 rather than 60 s. A circular scale, with numbers at each '5 s' position, was mounted at the external edge of the CRO screen, and a plastic grille on the peripheral portion of the screen displayed illuminated radial lines spaced at '2.5s.' intervals (each equal to 107 ms of actual time). Subjects were asked to maintain their gaze fixed on the centre of the CRO screen and not to follow the CRO spot around, even though they were to report information relating the 'clock-position' of the spot to the events (*see below*). The visual angle subtended between the centre and the peripheral position of the moving spot was small enough (1.8 deg) to present no difficulty from loss of visual acuity. The 'clock-time' of the CRO spot at each event, namely EMG with motor act or stimulator synch pulse with stimulus to skin, was recorded by the PDP-12 computer. Subjects were trained to make their self-initiated movement sufficiently brisk so that within no more than 10-20 ms from the start of any EMG potentials they achieved the amplitude pre-set to trigger the computer.

The subject was asked not to blink from the time the CRO spot started revolving until after the event. To minimize the possibility that the need to blink might become a controlling 'external' factor that compels or impels him to act, the subject was told that he may blink during the trial if the need arose; but that, if he did blink (or made some other extranaeous motion), he should then simply wait for the CRO spot to make at least another full revolution before performing the quick voluntary movement, as at the start of the trial.

Two different kinds of series were studied.

(1) *Self-initiated voluntary acts*. The subject was asked to wait for one complete revolution of the CRO spot and then, at any time thereafter when he felt like doing so, to perform the quick, abrupt flexion of the fingers and/or the wrist of his right hand (*see* Libet *et al.*, 1982). An additional instruction to encourage 'spontaneity' of the act was given routinely to subjects in Group 2 and only in the latter half to two-thirds of sessions with Group 1. For this, the subject was instructed 'to let the urge to act appear on its own at any time without any preplanning or concentration on when to act', that is, to try to be 'spontaneous' in deciding when to perform each act; this instruction was designed to elicit voluntary acts that were freely capricious in origin.

(2) *Skin-stimuli 'at unknown times'*. For such a series the subject expected to receive a near-threshold stimulus pulse on the back of the right hand. Delivery of the pulse was made by the operator at irregular times that were unknown to the subject, but only after the CRO spot completed its first revolution. They were actually delivered randomly during the second or third revolution of the spot (that is, between about 2.6 and 7.6 s after the spot began to revolve); this range overlapped with that for the times of the self-initiated movements. These conditions closely parelleled the attentive and other requirements associated with performing and recalling the CRO clock time for 'spontaneous' self-initiated voluntary acts (*see also* Libet *et al.*, 1982).

Subjects' reports of the time of an event. The 'clock position' of the revolving CRO spot at the time of the subject's awareness of an event was observed by the subject for later recall. Within a few seconds after the event, the subject was asked for his report of that timing, as in recalling a spatial image of ordinary clock time in conjunction with another event. It was emphasized that only an after-the-event recall of the experience was required, and that the subject should not worry about the task in advance of each event. Subjects became rapidly accustomed to this task during the training runs and did not find it to be taxing or stressful; nor did this task have any detectable effect on RPs (Libet *et al.*, 1982).

Modes of recall. Although each report depended on the subject having continously monitored the revolving CRO spot and visually noting, to himself, the position of the spot at the actual time of his awareness (of the event under study—*see below*), two different modes were employed for his after-the-event recall of that spot position. With the (A) or 'absolute' mode, the subject was asked to look back on the circular time scale mounted on the CRO and report the 'clock-time' of the spot position in 'seconds'. (Each 'second' on this scale corresponded to an actual time of 2560/60 or about 42.7 ms.) With the (O) or 'order' mode, the subject was asked to report the order of the final stopped position of the CRO spot, at the end of the trial, relative to his recalled position of the moving spot at the time of his awareness. For this, the subjects simply reported 'CRO spot (stop-position) first', at an earlier clock-position than the event-awareness; or 'awareness first', or 'together' (same position for both, insofar as the subject could discriminate). The (O) mode of recall was found by most subjects to be somewhat less demanding than the (A) mode.

The final stop position for the CRO spot following each event was arrived at in a complex manner that differed for (A) or (O) mode of recall. When either of the modes of recall was to be used, the computer continued the clockwise motion of the spot for a period beyond the time triggered by the event; this was called the 'contination interval'. The continuation interval could have one of 20 different values, all in the range between +500 and +800 ms (approximately 12 to 19 'seconds' of clock-dial). One of these continuation values was selected by the computer, from a randomized series of the 20, for use in a given trial. No violations of independence of answer were found in relation to the randomized continuation intervals.

For the (O)-order-mode only, however, the CRO spot did not stop after reaching its continuation interval; instead the spot jumped discontinuously, to stop at clock positions that were both before and after the subject's recalled positions for his awareness. (1) 'Stopping range'. The clock-times within which all of these final stop positions were included (the 'stopping range') ordinarily spanned 600 ms of real time. The positive and negative end points of the stopping range, relative to zero trigger time for each event (EMG or S-synch pulse), were chosen so as to span the entire range of times (relative to O) in the reports for a given awareness (W, M or S, *defined below*). We usually succeeded in setting the positive end of the stopping range well beyond the stop-times of the CRO spot for which all reports were 'W-first' (or M- or S-first), that is, earlier than the stopped spot position; and the negative end of the stopping range well beyond the stop-times for which all reports were 'spot first' (as in fig. 1B). Actual distributions varied with the subject. The beginning and end points of the 'stopping range' were therefore set individually before each series of trials, depending on previous results with the kind of awareness to be reported and with that subject (*see* examples in fig. 1); the training series of 10 trials that routinely preceded each regular series of 40 trials was useful for this purpose. (2) 'Stop-times'. Within each selected stopping range that spanned 600 ms, one of 40 different actual stopping times for the CRO spot, at intervals of 15 ms, was randomly selected by the computer for use after each of the 40 events. A different sequence of these randomized stop times could be preselected for the successive 40 trials in given series, so that a given sequence of stop-times was not repeated in a given session. The length of the 'continuation-interval', that precedes the final jump of the spot to its stop-time (*see above*), was randomly varied in a fashion that was independent of the randomized sequences selected for the final stop-times. The objective of all this was of course to avoid providing any clues that might relate the stop-time position of the CRO spot to the clock-time of the event itself.

The O procedure would not seem to be subject to the kind of artefactual difficulty described by Garner (1954). In the latter's case, subjects were asked to judge 'half-loudness' referred to a standard acoustic stimulus; each subject gave reliably consistent judgements, but these turned out to be appropriate only with reference to each different range of stimulus intensities presented rather than to the standard stimulus. In our case, the stopping range of reference times was determined for each subject from his own range of reported W times, as indicated by initial trials, rather than *vice versa.*

There were some series for which the adopted stopping range did not appropriately span the full range of potential reports by the subject; that is, the numbers of 'W first' and 'spot first' reports were far from equal, with few or no reports for one of these possible responses. This indicates that the subject was not shaping his reports to correspond to the adopted range of stop-times for the CRO spot. In such instances, the series had to be repeated, in the same or a later session, with a more suitable stopping range that could result in a statistically usable analysis for the mean W time in the series. Additionally, the subject had no prior knowledge of or consistent experience with the actual stopping ranges that were used. In a usual given experimental session, each separate series for W, M and S awareness times required a different stopping range. This meant that the subject did not have any consistent stopping range with which he was repeatedly presented in successive series.

Type of 'awareness' to be timed by the subject. Three different subjective experiences were to be timed. Each series of 40 trials involved reports of only one of these for all 40 events.

(W). In W series, the subject was asked to note and later report the time of appearance of his conscious *awareness of 'wanting' to perform* a given self-initiated movement. The experience was also described as an 'urge' or 'intention' or 'decision' to move, though subjects usually settled for the words 'wanting' or 'urge'. Subjects were told there were no right or wrong or inaccurate answers possible in the W and M series; that we simply wanted their best recollection and report of their own experience. Subjects were also asked, after completing a series of 40 self-initiated acts, whether any of the acts occurred without their experiencing any prior awareness of an urge or intention to act, that is, whether they were 'surprised' to realize a voluntary act had occurred without a conscious prior intention. In three series, subjects (3 of the 5 studied) did report that some, usually a small number, of the 40 acts 'surprised' them (Libet *et al.*, 1982), although the mean W time for such series of 40 was negative to EMG zero time, as usual. Asking subjects about 'surprise' acts should have indicated to them that it was acceptable even to have and to report the absence of a conscious urge or intention to act prior to a self-initiated act. The fact that instances of 'surprises' were reported increases confidence that the reports of timing prior to the act represented endogenous experiences not defined or induced by the instructions.

It was emphasized that the reported time should refer to the earliest appearance of the W awareness that might precede an actual movement; the subjects easily distinguished this specific urge to act from any awareness of a more general preplanning nature that might precede W, as in association with type I RPs (*see* Libet *et al.*, 1982), and also from an occasional urge to move that was not followed by an actual movement.

(M). In M series, the time of subject's *awareness* that he/she '*actually moved*', in the self-initiated act, was to be noted and reported after each trial. This was intended to provide an instruction for timing an experience related to but different from that of W, and thus to act as a partial test of the validity of the W timings. Some subjects stated, on their own, that their mental set differed somewhat in W *vs* M series. In a W series there was a feeling of active attention to or 'watching for' the awareness of wanting to move, so as to be able to note the time of its appearance, although the urge to move arose spontaneously with no preplanning; but M series proceeded without such advance 'watching' for the event to occur. It should be emphasized that any such difference in mental set did not appear to affect the associated RPs, which had similar forms and onset times for W and M series (*see* Results, *below*).

(S). In S series, time of *awareness of the sensation* elicited by the near-threshold stimulus pulse to the back of the hand, delivered at randomly irregular times unknown to the subject, was to be noted and reported after each trial. The attentive and other conditions of this task closely paralleled those for the W and M series, except that the event was an externally-induced sensory instead of a self-initiated motor one. After each S series, whether for training or experimental purposes, the subject was given a rough indication of how close he was to the actual times for the stimuli, as an aid in improving accuracy in all the experiments. If the awareness times reported in an S series were to differ significantly from the actual times of the stimulus pulse in each respective trial, the mean difference between the reported and actual stimulus times may be regarded as a measure of that subject's 'bias', when observing and reporting awareness times under the experimental conditions employed (*see* Libet *et al.*, 1979). This would include errors in making simultaneous judgements of the times for a mental event (sensation here) and a visual event (position of the CRO spot) (*see* Discussion). There were in fact mean differences or 'shifts' for S that were characteristic for each subject.

Progression of the experiments. The first (and, in some cases, the second) half-day session was purely for training purposes. Subsequently, each subject was studied in 6 to 8 regular half-day sessions, usually 1 per week. Each of the first 4 regular sessions began with a training series of 25 trials with skin stimuli intended as a retraining of reporting the recalled times of a subjective experience. This series differed from the experimental S series (of 40 trials) in that, after each 5 trials of this series, the subject was told what the actual 'clock-times' were for the skin stimuli, whose randomly irregular delivery times were not known before the trials. Following this there were two 40-trial series of self-initiated acts, one W and one M, each preceded by a briefer 10-trial series for retraining purposes, and then one 40-trial series of skin stimuli delivered at unknown times (S). The order of W and M series within a session was alternated for each successive session. A given mode for subjects to recall clock-positions of the revolving spot, (A) *vs* (O), was used for all series in a given session, but the modes were alternated for successive sessions. In sessions after the first 4, few M or S series were studied.

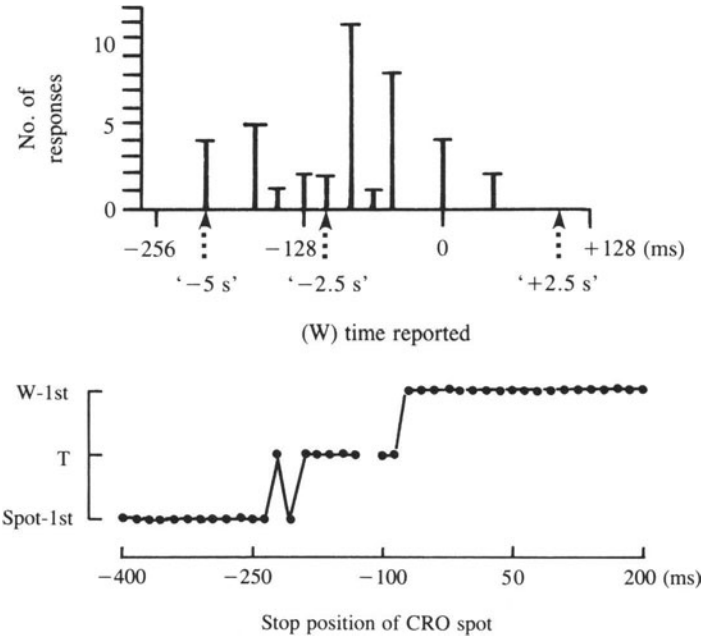

FIG. 1. Examples of plots of a subject's reports of (W) time after each trial in series of 40 self-initiated, voluntary movements. A, series in session 3 for subject S.B. mode of recall is 'absolute' (A); i.e. subject reported 'clock-time' of CRO spot at time of first awareness of 'wanting' to move. From this value, the 'clock-time' of the EMG-trigger was subtracted; the resultant net (W) time, relative to EMG zero time, was plotted. Abscissa indicates both the net 'clock-time' in seconds on the dial (arrows) and the corresponding net real times for (W). B, series in session 2 for subject S.B. mode of recall is by 'order' (O). The subject reported one of three alternatives for his recalled position of the revolving spot at the initial awareness of W. As indicated on the ordinate these were 'W-first' (W time earlier than the final stop-position of the CRO spot); or 'Spot-first'; or 'together', T (W time indistinguishable from or same as for the final stop-position of the spot). The 'stopping range', within which lay all the 40 different stop-positions of the spot, randomly sequenced in the series of 40 trials, was set between 200 ms positive to (i.e., later than) and 400 ms negative to the EMG zero time in each trial. (Since both ends of the 600 ms stopping range were included, the computer actually designated 41 stop-positions at 15 ms intervals, but the subject did not report W time for the 41st trial of the series. This accounts for an absence of a report at the stop-time of − 115 ms in the figure, which happened to be the randomly sequenced stop-time of the CRO-spot in the 41st trial of this series.)

Statistical handling of the response times. This is described in relation to the data in two actual series, one in (A) and one in (O) mode of recall (plotted in fig. 1). For each event in a series of 40 with (A) mode of recall, the 'clock-time' in 'seconds' for EMG-trigger time is subtracted from the 'clock-time' of the CRO spot at the time of awareness, as reported by the subject; this gives a net reported clock-time (relative to 'EMG zero time'). Each net reported clock-time is then converted to real time, and these W times (reported real time of each awareness of wanting to move, relative to EMG zero time) are plotted for that series. (Each 60 s of 'clock-time' = 2560 ms actual time.) For example, in fig. 1A we see that subject S.B. reported W times of 43 ms twice, O ms 4 times, −43 ms 8 times, etc. (as converted from net reported clock-times of 1, 0, −1 'seconds', respectively). Averaging these values for the whole series gives a mean shift for W, relative to EMG-O time, of −2.1 'seconds' of clock-time or −90 ms of real time.

For the (O) mode of recall we have extended to trinomial data the idea presented by Church and Cobb (1971). With this technique, the mean W shift was calculated as:

(upper, positive end of 'stopping range') − (time interval between 'stop times') × (number of points − 1/2)

'Stopping range' and 'stop-times' are defined above. 'Number of points' is calculated by giving 1 point for each time the subject says 'W first' (i.e. spot position at time of awareness has an earlier 'clock-time' than the final 'stop-time' of the CRO spot), and 1/2 point for each response of 'together' (i.e. W time and stop-time of spot appear the same to the subject). (In some series a trial was 'aborted' or a subject's report was not available, for some technical reason. In such a case that trial was considered to contribute a number of points equal to our estimate of the probability that the subject would say 'W first' for that particular 'stop-time' of the CRO spot.) In the example shown in fig. 1B, the responses for each of the different 'stop-times' are plotted. In that series, the upper end of the 'stopping range' was 200 ms after EMG-trigger time (lower end was −400 ms), with the usual minimum 15 ms time interval between stop-times within the 'stopping range' of 600 ms. There were 19 'W first' responses and 8 'Together' responses; the remaining responses were of course 'Spot first'. There was one trial with a missing report in this series, at the CRO stop-time of −115 ms; we estimate the probability of saying 'W first' as 1/2 in this case. Putting this together, our estimate of the mean shift for W is

$$200 - 15\,(19 + 8/2 + 1/2 - 1/2) = -145 \text{ ms}$$

The mean shifts for the awareness in an M or S series were computed in an analogous manner for A or O mode of recall, respectively, using the stimulator-synch trigger for zero time in the S series.

RESULTS

I. Subjective Timings

The mean values of the 40 reported times of awareness (whether for W, M or S), for each series in a given study session, are presented in Table 1, A. Each value is for net time relative to 'zero-time' for each event, that is, W or M relative to EMG zero time for activation of muscle in a self-initiated movement, or S relative to stimulus-pulse time in the case of skin stimuli delivered at irregular times. There were no obvious or consistent differences between sessions in which mode of recall of time was 'absolute' (A) or by order (O) relative to final 'clock-position' of the spot (*see* Methods).

The mean value of W in each series, that is of the recalled times for being aware of 'wanting' to move, was invariably in advance of or negative to the EMG zero time. The average of all such mean Ws was about −200 ms (Table 2D). Except for the nature of the event, the basic procedures for attentive monitoring of the revolving spot and of noting visually and later recalling the clock-position of the spot, in connection with appearance of an awareness, were the same for M ('actually moved') or for S (skin sensation produced by irregularly timed, stimulus pulse) as they were for W. Reported times for S might be expected on the average to be close

TABLE 1

Column A. Awareness times (W) and, column B, RP-onset times, for each 'W series' of 40 self-initiated movements. Awareness times also given for (M) and (S) series in same session. RP onsets are given for both the 'main negative shift' (MN) and for time at which 90 per cent of total area under the RP begins (*see* text for definitions of W, M and S). Column C. *Differences* (ms) between RP onset-times and W times ('uncorrected', and 'corrected' for S), taking RP onset either for the main negative (MN) component or for 90 per cent of the RP area, in each W series of 40 self-initiated acts. (Instances in each series of 40 trials when the W time preceded [was negative to] onset of RP are given after RP_{MN} onset for the respective series.)

			A. *Awareness times (ms)*						B. *Onset of RP (W series)*			C. *(Onset RP) minus (W), i.e. (B)-(A), using*			*(Onset RP) minus (W-S), using*	
		Mode re-call	*(W)*		*(M)*		*(S)*									
Sub-ject	*Ses-sion*		$\bar{X}$	*SE*†	$\bar{X}$	*SE*	$\bar{X}$	*SE*	*Type RP**	*Onset 'MN'*	*Onset 90 % area*	RP_{MN}	*Ws neg. to MN*	$RP_{90\%}$	RP_{MN}	$RP_{90\%}$
S.B.	1	A	− 54	11	− 21	15	− 12	11	II	− 550	−1076	− 496	0	−1022	− 508	−1034
	2	O	−145	19	− 48	20	− 53	15	II	− 900	− 729	− 755	0	− 584	− 808	− 637
	3	A	− 90	11	− 72	12	− 42	12	I	−1100	− 863	−1010	0	− 773	−1052	− 815
	4	O	−188	34	− 95	20	− 53	18	I	−1150	− 757	− 977	0	− 584	−1030	− 637
	5a	A	−123	16					II	− 800	− 876	− 677	0	− 753		
	b	A	−119	10					I	− 950	− 694	− 831	0	− 575		
	6a	A	−118	13			+157		I	− 900	− 685	− 782	0	− 567	− 625	− 410
	b	A	−161	15					II	− 600	− 484	− 439	0	− 323	− 282	− 166
G.L.	1	O	−208	28	−213	28	−147	28	II	− 500	− 380	− 292	0	− 172	− 439	− 319
	2	A	−422	24	−172	22	−184	30	I	−1200	− 755	− 778	0	− 333	− 962	− 517
	3	O	−377	27	−220	26	−217	30	I	− 900	− 635	− 523	0	− 258	− 740	− 475
	4	A	−258	21	−201	25	−120	25	II	− 800	− 593	− 542	0	− 335	− 662	− 455
	5a	O	−213	42					I	− 900	− 599	− 687	0	− 386		
	b	O	−283	34					I	−1200	− 866	− 917	0	− 603		
	6a	O	−221	34			−164	20	II	− 600	− 563	− 379	0	− 342	− 543	− 506
	b	O	−271	40					I	−1400	− 765	−1129	0	− 494	−1293	− 658
B.D.	1	A	−225	19	+ 92	10	+135	13	II	− 400	− 295	− 175	3	− 70	− 40	+ 65
	2	O	−145	24	− 3	25	+ 45	26	III	− 225	− 157	− 80	1	− 12	− 35	+ 33
	3	A	−152	14	+ 76	12	+ 61	9	II	− 500	− 401	− 348	0	− 249	− 287	− 188
	4	O	−142	18	+ 40	21	+ 90	20	II	− 425	− 469	− 283	0	− 327	− 195	− 239
	5a	O	−145	29					III	− 250	− 716	− 105	0	− 571		
	b	O	−108	46					III	− 325	− 210	− 217	1	− 102		
	6a	O	−146	30					II	− 650	− 468	− 504	0	− 322		
S.S.	1	O	−235	31	−168	25	−130	27	III_c	− 250	− 806	− 15	3	− 571	− 145	− 691
	2	O	−253	28	− 33	19	− 83	17	II_c	− 400	− 282	− 147	0	− 31	− 230	− 112
	3	O	−255	26	−153	24	− 75	24	II_c	− 400	− 281	− 145	2	− 26	− 220	− 102
	4	A	−283	19	−113	9	−157	13	III_c	− 300	− 695	− 17	17	− 412	− 174	− 569
	7a	A	−248	20					I_v	− 900	− 915	− 652	0	− 667		
	b	A	−236	17					II_c	− 400	− 604	− 164	4	− 368		
	c	A	−209	16					I_v	−1100	− 805	− 891	0	− 596		
C.M.	1 (30 trials)	O	−287		−138		− 63		II_c	− 500	− 408	− 213		− 121	− 274	− 184
	2	O	−223	25	−123	21	− 23	20	II_c	− 400	− 489	− 177	0	− 266	− 200	− 289
	3	O	−245	25	− 83	20	− 23	27	(no RP available)							
	4	A	−132	17	− 69	10	+ 29	10	II_c	− 600	− 520	− 468	0	− 388	− 439	− 359
	6	A	−211	13					II_v	− 400	− 781	− 181	1	− 570		
									II_c	− 400	− 227	− 181	1	− 16		
	7a	A	−260	17					I_v	−1000	− 703	− 740	0	− 443		
									I_c	−1050	− 694	− 790	0	− 434		
	b	A	−251	17					II_c	− 450	− 368	− 199	2	− 117		
	8	A	−204	16					II_c	− 475	− 479	− 271	1	− 275		

* All values for subjects S.B., G.L. and B.D. are for RPs recorded at the vertex. For subjects S.S. and C.M. the relevant RPs were recorded only at the contralateral precentral area for the hand, as designated by subscript c, except for some vertex recordings noted by subscript v. Simultaneous values for v and c are given for sessions 6 and 7a of subject C.M. † SE = standard error for our estimate of the mean value.

to zero (actual stimulus time) or possibly delayed slightly. But the actual mean values for S were usually negative rather than positive or delayed, except for subject B.D., and they differed for each subject and with each session. The value obtained for S in a given session could be regarded as at least a partial measure of the way the subject is handling those reporting factors that S and W series do have in common. As an approximation, one may 'correct' W for the subject's 'bias' in reporting awareness time by our methods, by subtracting S from W for that given session. The average of all W values (about −200 ms) would be changed to about −150 ms by subtracting the average of about −50 ms for all S values (*see* Table 2D).

TABLE 2. *GRAND AVERAGES* (MS) FOR ALL SERIES IN EACH COLUMN OF TABLE 1, ACCORDING TO TYPE OF ASSOCIATED RP AND TO ORDER OF W AND M SERIES IN A SESSION

Type of RP, for W series		A. *Awareness times*	B. *Onset of RP (in W series)*		C. *B-A; i.e., (Onset RP) minus (W), using*		*(Onset RP) minus (W-S), using*		
	n	*W*	RP_{MN}	$RP_{90\%}$	RP_{MN}	$RP_{90\%}$	*n*	RP_{MN}	$RP_{90\%}$
I	12	−233	−1025	−784	−825	−522	6	−950	−585
II	20	−192	−535	−527	−343	−333	14	−366	−323
III	5	−183	−270	−517	−87	−334	3	−118	−409

D. *Awareness times*

	W		*M*		*S*	
	n	$\bar{X}$	*n*	$\bar{X}$	*n*	$\bar{X}$
For all series	37	−204	20	−86	22	−47
In sessions when W series done before M series	10	−191	10	−92	10	−41
In sessions when M series done before W series	10	−240	10	−80	10	−53

Mean values for M series were also mostly negative (except for subject B.D.), averaging about −85 ms for all mean Ms (Table 2D). M was also slightly negative to S in almost every individual study session (*see* Table 1, column A); so that even if the average of M values (−86 ms) are 'corrected' by subtracting the average of S values (−47 ms), a small average net M of about −40 ms still remains. (Even for subject B.D., subtracting the average of his mean Ss, +83 ms, from the average of mean Ms of +51 ms in the same 4 sessions, produces a net 'corrected' average M of about −30 ms.) This produces the unexpected result that reported time of awareness of 'actually moving' generally preceded the activation of the muscle at EMG zero time! (*See* Discussion.)

It is important to note that mean W values were consistently negative to mean M values in the respective session for each subject (Table 1A), in spite of the frequently negative values for M. The average of all mean Ws (about −200 ms) indicated that awareness of wanting to move preceded average awareness of actually moving (about −85 ms) by more than 100 ms. When only those W values obtained in the same 20 sessions with M values are included, the average of mean Ws was −216 instead of −204 ms (Table 2D). Mean Ws obtained in sessions when an M series was carried out before the W series appeared to be significantly more negative than Ws obtained when a W series was carried out before an M series (*see* separate averages in Table 2D). A Wilcoxon test for this ranking order gave a one-sided $P = 0.038$, and a two-sided $P = 0.076$. (This ranking was not related to the use of (A) *vs* (O) mode of recall in the session.) However, the actual differences of about 50 ms between the two sets of Ws are relatively unimportant when comparing W times to onset times of the corresponding readiness potentials (*see* Section III, *below*).

II. Onset Times of Readiness-potentials (*RP*)

RPs associated with the freely voluntary, self-initiated movements employed in this study have been described (Libet *et al.*, 1982). They can be categorized into two or three types, based on their form and the time of the main negative (MN) shift (*see* Tables 1B and 2B). Type II (and III) RPs are obtained when all 40 self-initiated movements in the averaged series are reported by the subject to have originated 'spontaneously' and 'capriciously', with no recollections of preplanning experiences for any of the 40 events in the series. Additional experiences of a 'preplanning' phase are associated with type I RPs (Libet *et al.*, 1982). No significant association could be detected between mode of recall for W (that is (A) or (O)) and type of RP obtained.

Onset times of RPs listed in Table 1B are for RPs recorded in the same series of 40 self-initiated movements for which the reports of W times are given, in each respective session for each subject. This simultaneity, for RP and W observations, is important because there can be considerable variations of RP onsets in different series even in the same session (Libet *et al.*, 1982). The actual RPs for each W series listed in Table 1 for the Group 2 subjects (S.B., G.L. and B.D.) are presented in fig. 2. RPs were also obtained with each M series in the session, but onset times for these are not listed in Table 1. Onset times for RPs in M series were actually, on average, similar to those for RPs in the W series (*see also* Libet *et al.*, 1982).

Two values for onset time are given for each RP (W series) in Table 1B. (1) Onset time of the main negative (MN) shift was determined by 'eye-ball inspection', checked independently by a second investigator. (2) Onset time was also computed for the point at which 90 per cent of the area under the RP tracing preceded EMG zero time.

Onset time based on RP area was determined as follows. On an enlarged projected image, the area under the RP was measured for each interval of 50 ms, starting from EMG zero time and progressing to successive intervals in the negative (pre-EMG) direction until −600 ms; between −600 and −1400 ms, areas for 100 ms intervals were measured. Within each time interval, any areas below the baseline were subtracted from those above. In estimating total area, however, it was considered advisable to exclude any early brief shifts of potential that did not continue progressively into the main RP, as some of these

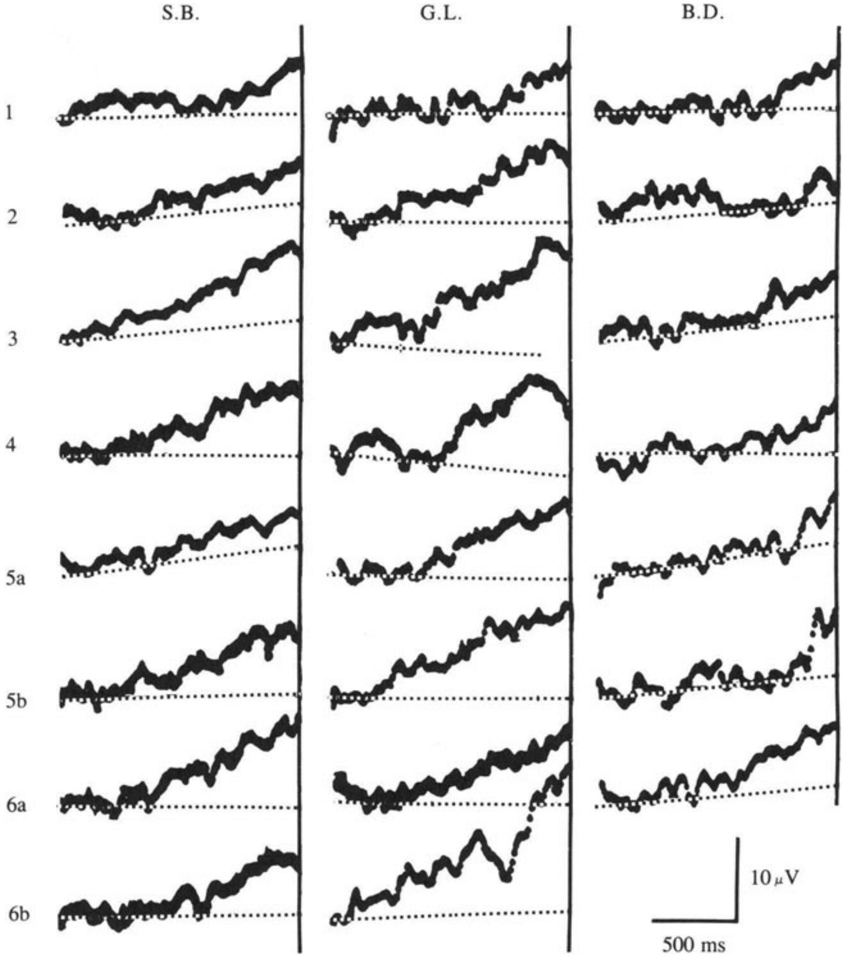

FIG. 2. Readiness-potentials (RPs) recorded at the vertex and averaged for each (W) series of 40 trials for subjects S.B., G.L. and B.D. Each RP corresponds to the respective (W) series as listed by session number in Table 1. The solid vertical line indicates the EMG zero time, marking the end of the RP. Dashed horizontal lines represent the d.c. baseline drift for the 2 s of that tracing, as estimated from the total voltage compensation for shift in d.c. level during the total time between beginning and end of that series of 40 trials.

could have been artefactual in nature. Therefore, the rule was adopted that any 200 ms segment having a total area $\leqslant 4\ \mathrm{mm}^2$ (actually equivalent to 50 μV-ms) was to be regarded as zero, and that any and all areas preceding that segment were also regarded as zero. (Making the rule even more stringent, by reducing the excluding low level segment to 100 ms, rarely changed the results significantly and, when it did, the final estimates of time of onset were very little different.) It was also recognized that measurements of the beginning of the negative potential shift are subject to some possible error in judging the d.c. baseline, especially in a somewhat noisy/bumpy tracing. Therefore, after arriving at a total area for a given RP under the rule above, the time interval that included only 90 per cent of this area was computed. The 90 per cent values also fit the range of differences between the independent measurements of the areas by two different investigators.

Averages of the onset times for RP_{MN} and $RP_{90\%}$ area, respectively, for the Ws series in Table 1B are given in Table 2. The initially slower but progressive ramp-like rise of type I RPs accounts for these onset times being more negative for RP_{MN} than for $RP_{90\%}$ area. On the other hand, in types II and III RPs some definitely distinguishable negativity is often present even before the main (MN) shift. Such negativities tend to have a relatively irregular, low, amplitude but there was no reason to regard them as other than actual RP components in these self-initiated acts (*see* Libet *et al.*, 1982). Their inclusion in the measurements of total area makes it possible for onset of $RP_{90\%}$ area to precede onset of RP_{MN} in some cases. Averages of the onsets for RP_{MN} and $RP_{90\%}$ were in fact not very dissimilar for type II RPs, although individual values for the difference ($RP_{MN} - RP_{90\%}$) were in a range between -207 and $+526$ ms; but for type III RPs average $RP_{90\%}$ preceded RP_{MN} by -247 ms (range of $RP_{MN} - RP_{90\%}$ was between -115 and $+556$ ms).

III. Differences between Onset time of RP and Time of Awareness of Wanting to Move

The data comparisons given in Table 1C are central to the objective of this study; they relate the time of appearance of the *conscious* intention to act, on the one hand, to the time of onset of the *cerebral processes* before the act (as evidenced in the RP), on the other. The *difference* between RP onset time and each W awareness-time is given for each respective series of self-initiated voluntary acts. Differences are presented when utilizing the W times as actually reported (W 'uncorrected'), giving (onset RP) minus (W); or the W times 'corrected' by subtracting the reported mean time for the S obtained in the same session, giving (onset RP) minus (W-S). 'Correcting' the W value by subtracting the S value of each subject's 'bias' in reporting, did not qualitatively change the relation of RP onset-time to W; rather it generally increased the difference by which onset of RP precedes W (as 'corrected'). For subject B.D., his *positive* values for S have the oposite effect; but even for him, the only qualitatively important change in the difference is introduced in session 1, which had a large positive S (+135 ms).

It may be seen (Table 1C) that, with few exceptions, onset of RP occurred before reported awareness time by substantial amounts of time. This was true irrespective of which measure of RP-onset or of W is employed to obtain the difference. The sizes and consistency of these differences, between onset of RP and W, indicate they are highly significant. However, it is difficult to produce a rigorous quantitative value for significance of the large differences between onset of RP and W. An SD (standard deviation) for variability among individual RPs within each series of 40 is not available, as only the average RP for the whole series could be meaningfully recorded. Consequently, only the mean W value and the averaged RP obtained in a given series can be compared for statistical purposes. Confidence in the significance of the differences (in Table 1C) is further raised by the fact that they were almost invariably very large when compared to the SEs (standard errors) for the mean values of W (Table 1A). In addition, each W series of 40 trials was examined for the incidence of individual W values that may have deviated sufficiently from the mean

W so as to be negative to (precede), rather than positive to (follow) the onset of average RP in that series (*see* Table 1C). For 36 W series of 40 trials each, instances in which individual W time preceded onset time of averaged RP numbered zero in 26 series and 1 to 3 in 8 series! (Of the remaining 2 series, in both of which RPs were recorded at contralateral precentral sites where RP onsets are often less steep than at the vertex, 1 had 4 and 1 had 17 instances. The latter large value holds only in relation to onset of MN in a type III RP but not if onset $RP_{90\%}$ is used.)

The SE of each mean value for W, as given in Table 1A, is more meaningful in relation to difference of (onset of averaged RP)-(mean W), than is the SD for the distribution of the individual W values in each series of 40 trials. (The SD for each series of 40 W values may be calculated using the respective SE, given in Table 1A; $SD = \sqrt{40} \times [SE]$.) If the individual RPs were available, the difference between each RP onset and the respective individual W value could be determined for each event, and a meaningful evaluation of variability for such individual differences could be made. However, in the absence of individual RP values, it is reasonable to assume that the W and RP-onset for each individual act are probably related in a dependent and positively correlated manner, in which onset of each RP tends to be negative to (before) each W. This condition seems likely because (1) W and RP are features of the same underlying process, (2) observed differences between averaged RP and mean W were consistently large, and (3) there was a nearly complete absence of individual W values that were negative to the averaged RP (*see above*).

For reporting each W time, subjects were asked to note the earliest awareness of the specific urge or intention to act which might occur prior to the act. All subjects reported that they could distinguish readily between this awareness and any experience of 'pre-planning' that sometimes occurred in acts associated with type I RPs (Libet *et al.*, 1982). Awarenesses of 'preplanning' were completely absent in series associated with type II (or III) RPs, in which all 40 self-initiated movements were 'spontaneous' in origin. Therefore, it is useful to consider the values for type II (and III) RP series separately from those for type I RP series, as summarized in Table 2A–C. As might be expected, series with type I RPs generally exhibit an earlier onset of RP, relative to W, than do those with type II (or III), especially for RP_{MN} onsets. However, even for the series of 'spontaneous' acts with types II and III RPs, onsets of RPs generally preceded W by substantial amounts. The average of the differences [(onset RP_{MN}) minus (W)] for the 20 series with type II RPs was -343 ms (Table 2C). The relatively few sessions in which these differences were possibly not significant occurred mainly in association with type III RPs, for which onsets of RP_{MN} averaged only -270 ms. For the 5 sessions with type III RPs, the average difference (onset $RP_{MN} - W$) was -87 ms, although when $RP_{90\%}$ is used, the difference increased to -334 ms.

DISCUSSION

It is clear that neuronal processes that precede a self-initiated voluntary action, as reflected in the readiness-potential, generally begin substantially *before* the reported appearance of conscious intention to perform that specific act. This temporal difference of several hundreds of milliseconds appeared fairly consistently regardless of which of the available criteria for onset of RP or for the time of awareness are adopted. Series with type II RPs are of especial interest as all of the 40 self-initiated acts arise spontaneously; on this and other evidence, the main negative (MN) shift with average onset about −550 ms was postulated to reflect the cerebral volitional process uniquely involved in initiating a freely voluntary, fully endogenous act (Libet *et al.*, 1982). Even for such series, with type II RPs, onset of RP preceded W by about 350 ms on the average. In series with type I RPs the earlier MN shift (average onset about −1025 ms) appears to reflect a more general preparation or intention to act that can be either endogenous or cued externally; it is not necessarily associated with freedom of choosing when to act (Libet *et al.*, 1982). However, actual experiences of 'preplanning' were reported for only a minority of self-initiated acts in series with type I RPs. Consequently, the much larger differences between onset of type I RP and W, on the average as much as −800 ms, may also reflect advance cerebral preparation that is generally accomplished before conscious intentionality arises. Only in the case of a small number of series with type III RPs was the difference between RP-onset and W less negative than −100 ms, when onset of MN shift (average −270 ms) is adopted. But if start of 90 per cent of RP area (average −517 ms) rather than MN shift is taken as the criterion for onset of RP, even these type III RP's precede W by an average of more than 300 ms (Table 2C). In series with type III RPs, all self-initiated acts were also spontaneous, as in type II (Libet *et al.*, 1982).

The validity of the RP as an indicator of cerebral activity had already been established (Kornhuber and Deecke, 1965; Deecke *et al.*, 1976; Pieper *et al.*, 1980). Actually, the onset of RP provides only a minimum timing for initiation of cerebral activity, as the recorded RP probably represents neuronal activity in a limited portion of the brain, possibly that of the supplementary motor area in the mesial neocortex (Deecke and Kornhuber, 1978; Eccles, 1982; Libet *et al.*, 1982). It is possible that cerebral activity is initiated at times earlier than the onset of the recorded RP in some other regions (*see* Groll-Knapp *et al.*, 1977). For the present issue, the requirement of averaging 40 individual RPs for each recordable RP might raise the question whether this obscures an actually randomized group of widely different onset times. Even in such a case, however, there are several considerations that work mathematically against an interpretation that W times are consistently equal to or precede onset times of individual RPs. Some of these have been discussed above (Section III, Results). An example might assume that the averaged RPs are contaminated by a small number of unusual individual RPs having very early onsets, compared to onsets of most RPs in each series of 40. However, if this were true, we would expect that such unusual RPs should not appear in an appreciable number of the 40-trial series, causing the order of times for W and onset of averaged RP to be reversed; but, in fact, the onset of averaged RP preceded mean W in all of the 37 W series (Table 1C, and *see above*). Furthermore, in type II RPs the main negative shift (MN) has a relatively abrupt onset and rises rapidly; any small number of individual RPs with unusually early onsets could not appreciably affect the onset time of RP_{MN}, as measured in type II RPs. Yet, onset of RP_{MN} preceded mean W, usually by large time intervals, in all the 20 W series that exhibited type II RPs. To circumvent all these points of evidence one would have to introduce unsupported assumptions that there exist specially biased distributions of RPs.

As another possibility, it might be proposed that neural activities, represented by individual RPs with randomly variable amplitudes and onset times, must achieve some threshold, whether integrative or other, before the brain 'decides' to act voluntarily; for this one might apply a kind of 'random-walk' model for sequential decision making (*see* Audley, 1973). If applied to our case, a delayed appearance of a 'neural threshold' might coincide in time with the W time, and thus nullify any apparent discrepancy between time of cerebral decision and time of conscious intention to act. But a consistent bias or change in the random-walk distribution of the variable neural functions would have to be initiated at the onset of averaged RP, preceding the achievement of threshold for the decision. This would be analogous to the required initiation and presence of a sensory signal to produce the distribution of sensory random variables that may lead to a yes-no decision in that random-walk model (Green and Luce, 1973). Therefore, such a proposal could, at best, only separate the cerebral initiating process into two stages. An earlier stage, which would precede a final decision stage, would start with some initiating endogenous trigger. Such a model would not fundamentally affect our conclusion, that cerebral activity initiates the voluntary act before reportable conscious intention appears.

The Criteria for Time of Conscious Intention to Act

The reliability and validity of these operational criteria are of course crucial to the issue of the temporal order of cerebral processes *vs* conscious intention. The reliability of the subjects' reports of 'clock-position' for the revolving CRO spot at the time of awareness appears to be fully adequate (*see* discussion of SEs of mean W values and incidence of individual W values, relative to onset of averaged RP, in Section III of Results).

Consideration of validity of our criteria begins with the premise that the subjective event in question is only introspectively accessible to the subject himself, and that this requires a report by the subject (*see* Libet, 1965, 1966; Nagel, 1974; Creutzfeldt and Rager, 1978). Any behavioural response that is not a direct function of such a report could not be used as a *primary* indicator of the subjective event (Libet, 1981*a*, *b*), although it might be found to be associated with the subjective event as studied by suitably valid reports. Acceptance of this premise, and of our specific operational precedure for the required introspective report, introduces several issues that may affect the validity of the reported W time. In particular, factors that may affect the transmission between the subject's introspective experience and his verbal report must be considered.

(1) *Simultaneity of judgements.* Our method requires the subject to observe simultaneously, for later report, the appearance of a mental event (conscious urge to move) and the visual clock-position of the revolving spot of light at that time. Reports of simultaneous events have long been known to be subject to potential errors, depending on the circumstances (differential attentiveness, in the 'prior entry' phenomenon) and on the individual subject (*see* Boring, 1957; Efron, 1973; Sternberg and Knoll, 1973). Our S experimental series, in which subjects reported awareness times for skin stimuli, were designed to serve as controls for potential

errors in such 'simultaneity' as well as for other individual biases and errors in the entire reporting procedure. Procedures and requirements for subject's attentiveness, observations and later recall, of clock-positions of the revolving CRO spot at the time of awareness of a randomly appearing skin sensation, were the same as in the W and M series. But in the S series the actual time of the stimulus was later known to the investigator, and the error in the subject's reports could be determined objectively. The bias or error found in the S series did not qualitatively alter the difference between onset of RP and W, as determined in a given session for the same subject; in fact, they generally enlarged the differences (Table 2C).

(2) *Timing of an endogenous mental event.* The subject's reported time for spontaneously arising awareness of the urge/intention to move cannot be directly or objectively validated in the manner possible for skin stimuli in the S series. The subject's report constitutes the primary evidence of his introspective experience. No other independent measure of such subjective timing is available, although some of the other available evidence can affect confidence in the validity of the observed timings; this is summarized below in point (3).

It is of course possible to conceive or postulate conditions that might introduce discrepancies between the actual and the reported initial times of such an awareness. For example, what if it were possible to judge accurately only the end of the mental event, the conscious urge to move; the actual time of its onset, in relation to a perceived clock-time, would then be unknown and in doubt. In relation to such a suggestion we note, first, that each subject was instructed to 'watch for' and report the earliest appearance of the awareness in question, and subjects did not raise any difficulties about doing this. Secondly, perceptual timings of onset and offset found for a peripherally induced sensation, at least, do not support the suggestion that only the end is accurately judged. Using a method of cross-modality simultaneity judgements, Efron (1973) found that (a) there was no difficulty in distinguishing onsets from offsets; (b) the perceptual onset latency was constant regardless of large changes in duration of the stimulus; whereas (c) perceptual offset latency could in fact vary when stimulus durations were shortened to < 150 ms, with the change in offset latency probably originating, in part, in the peripheral sensory structures. Somewhat related findings on perceptual onset latencies are available for a cerebrally induced mental event, elicited by a stimulus in the somatosensory system in man (Libet *et al.*, 1979). The mean differences between perceptual timings, for a brief skin stimulus relative to onset of a medial lemniscus stimulus lasting 200 ms, were only within a few tens of milliseconds. One might suggest that timing of an endogenous mental event, the spontaneously arising conscious intention to act, may be more difficult subjectively to pinpoint with accuracy than the timing even for the sensation elicited by an intracerebral stimulus in the medial lemniscus. The individual W values reported by our subjects in a given series of 40 events did show variability; but the difference between (onset of RP) and (mean W), in Table 1C, was consistently and considerably greater than the SE of mean W for the respective series. Actually, the converse possibility, of W times reported earlier than the actual time of awareness of the urge to move, presented a more real difficulty. A 'preawareness' that one is preparing to perform the voluntary act, sometime within the next second or so, does in fact accompany at least some of the events in those series that produce a type I RP, as noted above (Libet *et al.*, 1982). If such a preawareness were to have affected the report, it would mean that the reported W times were more negative, earlier, than they should have been; the difference between onset of RP and 'real' W should then be even greater than indicated by our results. However, in series giving type II RPs, all of the self-initiated acts were described as 'spontaneous'; the subjects reported that each urge or wish to act appeared suddenly 'out of nowhere', with no specific preplanning or preawareness that it was about to happen.

Finally, the possibility could be raised that an earlier nonrecallable phase of the conscious urge exists, one that is not storable as a short-term memory. If it is further assumed that the subject's report of W time requires short-term memory of the mental event, then the reported time would apply only to a later, recallable phase of awareness, given such assumptions. First, one should note that, to report W time, the subject needed to recall only the clock-position of the revolving spot at the time he became aware of the urge/intention to move, and not necessarily the conscious mental event itself. (Actually, the latter was at least often recallable, as the subjects were able to describe it, even in relation to experiences just preceding it during the trial.) Secondly, the proposal of a nonrecallable initial phase of the conscious urge to move is a hypothetical construct which, like some other potential uncertainties in timing an endogenous mental event, is at present not directly testable. Thus, although it cannot be definitively excluded, it also lacks experimental support.

(3) *Additional evidence bearing on the validity of the reported timings*. One way to test and improve confidence in the validity of the reported timings lies in using different but converging modes of observing and reporting, with each mode having independent validity without further assumptions (*see* Garner, 1954, for discussion of this approach in connection with a related issue). Two quite different modes were employed for reporting the 'clock-positions' of the CRO spot at the time of awareness, that is, the absolute (A) reading *vs* the order (O) relative to final spot positions. Yet both modes produced values for W in the same range and were essentially indistinguishable. (This also held for reported timings in the M and S series.)

Subjects definitively distinguished the experience and time of awareness of wanting to move (W) not only from those of a skin sensation (S) but also from awareness of actually moving (M). Mean values for W times were consistently negative (by > 100 ms on average) to those for M times (Tables 1A, 2D). This was true in spite of the unexpected finding that mean M values were themselves generally negative to EMG zero time, although they were only slightly negative to S values in which no movement was involved. M has some features of an endogenous mental event, rather than simply of a sensation elicited by input from peripheral sensory sources (*see below*, for discussion of M preceding the EMG). On the other hand, onset-times for type I or II RPs in series asking for W reports were generally similar to those asking for M reports, or even to those in series when no reports of awareness were requested (*see also* Libet *et al.*, 1982). This indicates that the somewhat different mental sets associated with each kind of reporting (or absence of reporting) did not affect the RP side of the time differential with respect to W.

It might be argued that subjects' reports of W times could be distorted by their awareness of the time of the actual movement; this might induce them to report W times that are later than the actual time of appearance of the conscious intention to move. But the subjects confirmed that for W reports they concentrated on noting their *earliest* awareness of any urge/intention to move. They further stated that their mental set for 'observing' W time was also different from that for M time.

Furthermore, the available evidence indicates that the subjects' experience with attending to the awareness of actually moving (M) may have induced them to report W times that were somewhat more, not less, negative relative to EMG zero time (*see* Results, end of Section I). The mean W values were on the average about 50 ms more negative when, in a given session, the W series was performed after instead of before an M series (*see* Table 2D, etc.).

Awareness of 'actually moving' (M) preceded the EMG. Mean M values were generally negative to EMG zero time for most subjects, and consistently though slightly negative (average about −40 ms) relative to S values for all subjects. Timing of M so as to precede the activation of muscle contraction indicates that M was not reflecting awareness of proprioceptive sensory impulses elicited by the movement. It suggests the possibility that M reflected an awareness associated more immediately with initiation of efferent cerebral output for the movement. Components that follow the main negative RP shift are recordable just prior to movement, including a negative 'motor potential' that begins about 50 ms before the EMG (*see* Deecke *et al.*, 1976; Shibasaki *et al.*, 1980).

Unconscious and Conscious Initiation or Control of Voluntary Acts

Since onset of RP regularly begins at least several hundreds of milliseconds before the appearance of a reportable time for awareness of any subjective intention or wish to act, it would appear that some neuronal activity associated with the eventual performance of the act has started well before any (recallable) conscious initiation or intervention could be possible. Put another way, the brain evidently 'decides' to initiate or, at the least, prepare to initiate the act at a time before there is any reportable subjective awareness that such a decision has taken place. It is concluded that cerebral initiation even of a spontaneous voluntary act, of the kind studied here, can and usually does begin *unconsciously*. The term 'unconscious' refers here simply to all processes that are not expressed as a conscious experience; this may include and does not distinguish among preconscious, subconscious or other possible nonreportable unconscious processes.

A general hypothesis had already been proposed that some substantial time period of appropriate cerebral activity may be required for eliciting all specific conscious experiences (Libet, 1965). This developed out of experimentally based findings that cortical activities must persist for up to 500 ms or more before 'neuronal adequacy' for a conscious sensory experience is achieved (*see* Libet, 1966, 1973, 1981*a*; Libet *et al.*, 1972). In that hypothesis, those cerebral activities that did not persist sufficiently would remain at unconscious levels. The present evidence appears to provide support for that more general hypothesis. It suggests that a similar substantial period of cerebral activity may also be required to achieve 'neuronal adequacy' for an experience of conscious intention or desire to perform a voluntary act.

The present evidence for the unconscious initiation of a voluntary act of course applies to one very limited form of such acts. However, the simple voluntary motor act studied here has in fact often been regarded as an incontrovertible and ideal example of a fully endogenous and 'freely voluntary' act. The absence of any larger meaning in the simple quick flexion of hand or fingers, and the possibility of performing it with capriciously whimsical timings, appear to exclude external psychological or other factors as controlling agents. It thus invites the extrapolation that other relatively 'spontaneous' voluntary acts, performed without conscious deliberation or planning, may also be initiated by cerebral activities proceeding unconsciously.

These considerations would appear to introduce certain constraints on the potential of the individual for exerting conscious initiation and control over his voluntary acts. However, accepting our conclusion that spontaneous voluntary acts can be initiated unconsciously, there would remain at least two types of conditions in which conscious control could be operative. (1) There could be a conscious 'veto' that aborts the performance even of the type of 'spontaneous' self-initiated act under study here. This remains possible because reportable conscious intention, even though it appeared distinctly later than onset of RP, did appear a substantial time (about 150 to 200 ms) before the beginning of the movement as signalled by the EMG. Even in our present experiments, subjects have reported that some recallable conscious urges to act were 'aborted' or inhibited before any actual movement occurred; in such cases the subject simply waited for another urge to appear which, when consummated, constituted the actual event whose RP was recorded (Libet *et al.*, 1982). (2) In those voluntary actions that are not 'spontaneous' and quickly performed, that is, in those in which conscious deliberation (of whether to act or of what alternative choice of action to take) precedes the act, the possibilities for conscious initiation and control would not be excluded by the present evidence.

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