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Barking up the wrong free: readiness potentials reflect processes independent of conscious will

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Title: Barking up the wrong free: readiness potentials reflect processes independent of conscious will

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Abstract:
In the early 1980s Libet found that a readiness potential (RP) over central scalp locations begins on average several hundred milliseconds before the reported time of awareness of willing to move (W). Haggard and Eimer (1999) later found no correlation between the timing of the RP and W, suggesting that the RP does not cause W. But they did find a positive correlation between the onset of the lateralized readiness potential (LRP) and W, suggesting that the LRP might cause W. Here we report a failure to replicate Haggard and Eimer's LRP finding with a larger group of participants and several variations of their analytical method. While we did find a between-subject correlation in one of 12 analyses of the LRP, we crucially found no within-subject covariation between LRP onset and W. In additional experiments, we explored the nature of the RP and LRP by testing their relationship to anticipation and/or preparation for action. These results suggest that the RP and LRP reflect processes independent of will and consciousness. This conclusion has significant implications for our understanding of the neural basis of motor action and potentially for arguments about free will and the causal role of consciousness.

Keywords: Readiness Potential, Libet, Volition, Consciousness, Free Will

Introduction

Although our conscious will appears to cause our actions, Benjamin Libet's experiments raised doubts about this apparent causal connection (Libet et al., 1983ab, 1982; Libet, 1985). Libet and colleagues had subjects make simple motor movements, such as lifting a finger, while they measured a particular EEG marker of brain activity time-locked to the motor act. This marker—a negative potential over central scalp locations that develops in the seconds before participants make self-initiated movements—has been dubbed the "readiness potential" or RP (also known as a 'Bereitschaftspotential' or BP; cf. Kornhuber & Deecke, 1965). Libet and colleagues estimated the earliest conscious awareness of a will to move by asking subjects to recall where a rotating spot on a clock face had been at the moment they were first aware of an urge to move. Libet and colleagues found that the RP occurred on average 350 ms before the reported time of awareness (W). This finding has been replicated many times (e.g. Fried et al., 2011; Haggard and Eimer, 1999; Lau et al., 2004; Sirigu et al., 2004). Neural activity reflected by the RP reliably predicted an imminent voluntary action and also preceded the time at which participants reported becoming aware that they were about to act. Because a cause must precede its effect, Libet concluded that conscious will could not be what initiates the causal process that leads to action.

Libet's results raise a crucial question: Is the RP part of a causal chain that is sufficient to produce seemingly voluntary action without any essential intervening causal role for will or for consciousness? If so, the efficacy of will and consciousness along with moral responsibility are all in doubt. In the end, Libet did not deny free will but instead postulated a veto power that could stop the execution of unconsciously initiated actions. However, many scientists and philosophers still use Libet-like results to argue against the existence of free will and responsibility (cf. some authors in Sinnott-Armstrong & Nadel, 2010).

Despite three decades of theorizing about Libet's findings, the precise role of the RP has not been empirically established. It is still unclear whether the RP is a neural correlate of planning a motor act, anticipating a motor act, preparing to perform a motor act, consciously willing a motor act, or a combination of these. It is also still not clear if an RP causes a conscious will to act, directly causes the act itself, or reflects processes that are causally unrelated to the act.

To our knowledge, Haggard and Eimer (1999) conducted the only study that has claimed to have found evidence supporting a causal relationship between readiness potentials and conscious will. Their argument was based on Mill's (1843) observation that a necessary condition of causal relations is covariation of causes and effects. Haggard and Eimer found that the RP did not covary with W, which undermines a causal relationship between the two. However, they did report a correlation between W and the onset of the lateralized readiness potential (LRP). The LRP is a difference in scalp potentials between the two hemispheres that develops over the motor cortex shortly before participants make a lateralized movement, such as a left or right hand button press. This correlation leaves open the possibility of a causal relation between the LRP and W.

Unfortunately, Haggard and Eimer's (1999) results used data from only 8 subjects. Their table of early vs. late awareness LRP onsets indicates that the effect was driven largely by participants 3 and 6. If either of these two participants had been removed from the analysis, the effect would no longer have reached significance. We therefore attempted to replicate their original finding with a larger sample and then to clarify the nature of the RP and LRP and their relation to awareness, will, and action.

Experiment 1: Attempted Replication of Haggard and Eimer (1999)

Experiment 1 Methods

We followed Haggard and Eimer's methods, which used the traditional Libet paradigm. Participants sat 50 cm from a computer monitor on which we displayed an analog clock with a 1.3 cm-long hand rotating clockwise once every 2560 ms. Clock positions were labeled with the numbers 1 through 12. Participants performed the same number and type of trials as in Haggard and Eimer: 40 trials each of free or fixed movements, judgments of W or M (the time at which they actually moved), and left or right button presses, totaling 320 trials for each approximately hour-long session. For W trials, participants were told to report “when you first began to prepare your movement,” and for M trials, “when you pressed the key,” consistent with the instructions of Haggard and Eimer. Participants reported times in clock units which were converted to milliseconds.

21 participants (9 females, 20 right-handed) with mean age 28.9 years (S.D. 11.6 years) gave consent to participate. One participant only completed half of the experiment due to a computer program error, and one participant's data were discarded before further analysis because of excessive noise. EEG data were recorded at 2048 Hz using BioSemi Ag/AgCl high impedance active electrodes located at 32 scalp locations according to the 10-20 system (Jasper, 1958), on the left and right mastoids, and on the back of each index finger. Only eight of these electrodes—at Fpz, Fz, Cz, Pz, C3, C4, and the two mastoids—were used in the analyses. Scalp data were referenced offline to the average mastoid signal, bandpass filtered from 0.016-70 Hz, and epoched from 2600 ms before to 400 ms after each key press. Each epoch was baseline shifted using the average signal from -2600 ms to -2500 ms. Epochs deviating more than 80μV from baseline at Fpz or Pz were rejected to eliminate eye artifacts. On average 18.8% (S.D. 22.2%) of trials were rejected for each participant due to either participant error or eye artifact. The RP was measured at Cz and the LRP was measured at C3 and C4.

Experiment 1 Results

Our results replicated those of Haggard and Eimer for fixed vs. free and M trials: manipulating whether movements were fixed or free did not affect the RP, LRP, M, or W. While Haggard and Eimer’s paradigm did not allow for an exact measurement of RP onset, we also clearly replicated Libet’s original finding: mean W was -196 ms (S.E. 31.9 ms) relative to the key press, mean RP onset occurred at or before the start of our epoch at -2600 ms, and mean LRP onset as measured by Haggard & Eimer (see below) was -779 ms. As our primary concern was to investigate whether LRP onset is correlated with W, we will only report results relating to early vs. late W trials in order to address Haggard and Eimer’s main finding.

Haggard and Eimer used pre-movement RP amplitude as an indication of RP latency, so we followed their method. Like them, we found no significant differences in RP amplitude from -1000ms to -500ms between early and late W trials (see Figure 1 for grand mean time courses). The mean RP amplitude during this time period was -6.649 μV (S.E. 1.197 μV) for early W trials and -6.677 (S.E. 1.426 μV) for late W trials [$t(19)=0.03304$, $p=0.9740$]. This result supports their conclusion that the RP does not covary with W.

However, we did not reproduce their LRP finding. Haggard and Eimer calculated LRP onset by fitting each pre-movement time course to a function defined piecewise as a linear portion followed by a linear + quadratic portion. The “join point,” which is the time point at which the linear transitioned to the linear + quadratic portion, was defined by them as the time of LRP onset. We used their method and found no significant differences between early and late W trials. LRP onset was -719 ms (S.E. 119 ms) for early W trials and -851 ms (S.E. 124 ms) for late W trials [t(19)=0.8574 (one-tailed), p=0.7990]. Note that these values trend in the opposite direction one would expect if the LRP caused W, with LRP onset occurring earlier for late W trials. We analyzed the data twice more using different definitions of LRP onset: once using 50% peak latency and once with 25% peak latency. In both cases we found no significant difference between early and late W trials. Mean 50% peak latency was -383 ms (S.E. 64 ms) for early W trials and -426 ms (S.E. 86 ms) for late W trials [t(19)=0.4086 (one-tailed), p=0.6563]. Mean 25% peak latency was -695 ms (S.E. 108 ms) for early W trials and -647 ms (S.E. 130 ms) for late W trials [t(19)=-0.3864 (one-tailed), p=0.3517].

Because the LRP is a relatively small signal relative to the level of noise in EEG signals, we considered the possibility that our single-subject means were too noisy to adequately resolve the LRP onset. Miller, Patterson, and Ulrich (1998) suggest using a jackknife procedure for assessing LRP onset latency differences between conditions. In a jackknifed analysis with N subjects, N grand means of the data are calculated, each with one subject left out. The analysis is then performed on these grand means with corrections applied for the jackknife-induced decrease in variance. In the case of noisy estimates such as occurs when calculating onsets from single-subject LRP time courses, this procedure can provide cleaner results while not biasing estimates of significance. We tried jackknifed versions of each of the three analyses above but still did not find significant differences between early and late W trials (see Figure 2 for results of these within-subject analyses).

To test whether we could find any covariation at all between LRP onset and W, we performed between-subject correlation analyses comparing W with the above measures calculated on each participant's average time course (no longer split between early and late awareness trials). Of the six analyses we performed, only one was significant, namely the correlation between jackknifed W and LRP onset as defined by Haggard and Eimer (r^2=0.412, p=0.002). Figure 3 shows scatter plots for these six between-subject correlation analyses.

In sum, we found no within-subject covariation between LRP onset and W and no significant between-subject covariation between LRP onset and W except in one test (to be discussed below). Table 1 summarizes the results from the 12 LRP analyses. Overall, Experiment 1 suggests that the RP and LRP do not correlate with—and, hence, cannot cause—the conscious experience of will.

Experiments 2 and 3: What is indexed by the RP and LRP?

If the RP and LRP are not causes of conscious will, what processes do they reflect? Might their timing correlate with the timing of something other than W? Are they neural correlates of planning a motor act, anticipating a motor act, preparing to perform a motor act, or some combination of these? To clarify the potential correlates of the RP and LRP, we conducted two additional experiments.

Experiment 2 Methods

Experiment 2 used a classic go/no-go paradigm. Each of 9 participants (4 females, 8 right-handed, mean age 29.7 years [S.D. 9.58 years]) sat 50 cm from a computer monitor and watched a 7 Hz (80 ms on), 3.8 cm-tall rapid serial visual presentation (RSVP) stream of blue-hued letters. 3.5-8.5 seconds after the letter stream began a green or red letter appeared (the imperative stimulus) instructing the participant to press (go) or not press (no-go) a key, respectively. The RSVP stream continued for 2 seconds after the imperative stimulus. Participants were told that on some trials they would see a

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warning stimulus before the imperative. In these trials, the RSVP letters changed color gradually from blue to yellow, starting from the top and bottom and moving continuously toward the middle before the imperative stimulus; the completion of this color replacement coincided with the appearance of the imperative. In one third of the trials, this yellow warning stimulus started 1.5 seconds before the imperative. In one third of the trials, the warning began 3 seconds before the imperative, and in one third there was no warning before the imperative. In half of the trials participants were instructed to use their left hand and in the other half their right hand. Participants were paid based on their reaction time and lost half of their earnings above a baseline amount if they responded before the imperative stimulus or during a no-go trial. Conditions were randomized per trial, with 20 trials per condition and 240 trials total in each approximately hour-long session. Data were collected as in Experiment 1 with the addition of electrodes placed on the outer canthii as well as superior and inferior to the right orbital. The data processing procedure was also the same except baselines were calculated from -3500 ms to -3000 ms and epochs for LRP calculation were corrected for potential eye blink and movement artifacts prior to rejection (Joyce, Gorodintsky, & Kutas 2004). Results are not shown for trials with the 1.5 second warning stimulus.

Experiment 2 Results

In order to investigate situations in which the RP and LRP do or do not arise, Experiment 2 revisited the go/no-go paradigm that has in the past been used to investigate a scalp potential called the contingent negative variation (CNV). Classically, the CNV, like the RP, is a slowly developing negative potential that occurs at the central scalp location called Cz. While this potential is called an RP when movement is voluntary, the term CNV has been used when participants move in response to an imperative stimulus after having been forewarned of the time at which the imperative stimulus will occur (Walter et al. 1964; Brunia, Boxtel, & Böcker 2011). Thus, the RP and CNV are analogous potentials that past studies have distinguished largely by whether movement is voluntary or cued externally. In this experiment we compared conditions in which: a) movement occurred with a warning (“Go” imperative preceded by a warning stimulus), b) movement occurred without a warning (“Go” imperative not preceded by a warning stimulus), and c) movement did not occur after a warning (“No-go” imperative preceded by a warning stimulus). Figure 4 shows RPs and LRPs derived from each of these cases. The RP occurred if and only if participants could anticipate and prepare for the moment at which they may be instructed to move (Figure 4a, comparing cases a and b above), but the RP did not depend on certainty that they would be required to move or whether or not they actually executed the movement (Figure 4c, comparing cases a and c). In contrast, the LRP occurred only if participants executed their movement (Figure 4d), regardless of whether or not they were warned beforehand (Figure 4b) and, hence, regardless of whether or not they anticipated moving.

These results suggest that the RP is related to anticipation of movement but not to production of movement, whereas the LRP is related to production of movement but not to mere anticipation of movement.

Experiment 3 Methods

Experiment 3 investigated different kinds of anticipation and preparation that might give rise to the RP, using a variation of a previous study by Donchin et al. (1972). Each of 10 participants (4 females, 10 right-handed, mean age 23.5 years [S.D. 2.80 years]) completed four blocks of tasks using stimuli analogous to those in Experiment 2 except that the warning stimulus was always present for 3 seconds before the imperative. In block one, the “Go” block, participants knew that the imperative stimulus would always instruct them to move. Participants were paid based on their reaction time. Block two, the "Go/No-go" block, was similar to Experiment 2. In block three, participants merely anticipated a stimulus without an associated motor task. In this "Predict" block, participants predicted before each trial began whether the imperative stimulus would be the letter "L" or the letter "R". They indicated their prediction with a button press and then merely watched the RSVP stream. Participants were paid only if they guessed correctly. In the fourth "Compute" block, the imperative stimulus was a green or red number that participants were instructed to add to or subtract from, respectively, a running total that they maintained in working memory. Participants were paid based on the difference between their reported total and the true total. Each block consisted of 80 trials, totaling 320 trials during each approximately 1.5 hour-long session. Data were analyzed as in Experiment 2 with the addition of a 7 Hz notch filter to reduce the effects of the visual evoked potentials due to the RSVP stream and time locking to the imperative stimulus.

Experiment 3 Results

The RP was observed in all trials regardless of whether participants prepared for movement, prepared for a non-motor task, or merely anticipated a relevant stimulus. However, the magnitude of the RP, as measured by the mean amplitude between -1000ms and 0ms, differed between tasks as follows: -6.98 µV (S.E. 1.86 µV) for the "Go" task, -5.61 µV (S.E. 1.93 µV) for the "Go/No Go" task, -2.50 µV (S.E. 1.84 µV) for the "Predict" task, and -3.00 µV (S.E. 1.11 µV) for the "Compute" task. These differences reached significance in a repeated measures ANOVA ($F(3,27)=3.89$, $p=0.0197$). Figure 5 shows the grand mean RP for each condition.

General Discussion

Several decades ago, Kornhuber and Deecke discovered an electrocortical potential that preceded volitional motor action. They called this response the Bereitschaftspotential and it later came to be known as the *readiness potential*. Subsequently, the seminal experiments of Libet suggested that the onset of this potential precedes awareness of the urge to move, a finding apparently at odds with lay views of free will. In the decades since, researchers have sought to answer exactly how the RP, and the associated lateralized RP (LRP), relate to conscious will. In one of the most important contributions to this literature, Haggard and Eimer reported that the LRP is temporally yoked to the feeling of will, suggesting that the LRP might cause W. In Experiment 1, we sought to replicate this finding and failed. In Experiments 2 and 3, we sought to determine whether other features of action, such as anticipation, preparation, and execution are correlated with the RP and/or LRP.

Does the LRP cause awareness of an intention to move? Causation requires two facts to be true: (1) the cause precedes the effect and (2) the timing of the cause is correlated with the timing of the effect. If either of these does not hold, then there is no causal relation. Thus, if the LRP does not precede awareness related to an intention to move, or if the timing of LRP onset is not correlated with the timing of awareness, then the LRP does not cause an awareness of an intention to move. We consider these two issues in order.

(1) Does LRP onset precede awareness? We replicated the original Libet finding that the onset of the RP precedes reports of timing of awareness of wanting to move (Libet's "W"). We also

replicated Haggard and Eimer's (1999) finding that the onset of the LRP, while later than the RP, also precedes W. However, an intention to move may unfold over time and arise at multiple levels of processing. It is possible that the awareness of wanting to move, reported at the time of W, is a final stage of a process that begins much earlier, perhaps even before the beginning of the LRP. In an attempt to address this, Matsuhashi and Hallett (2008) adopted a probe paradigm to assess stages at an earlier potential level of relevant processing. In their study, Matsuhashi and Hallett reported that "the time when subjects have access to movement genesis as intention" could be accessed via an external probe more than one second before W. They dubbed this time "T" and found that it occurred on average 1420 ms before movement. This is well before the LRP onsets we measured, which occurred around 500 to 850 ms before movement. Thus, some information that subjects can use to infer the genesis of a motor intention was available to probed subjects after the RP but before the LRP.

(2) Does LRP onset covary with awareness? Our main question was whether we could replicate Haggard and Eimer's principal finding that tied LRP onset to W. This replication would more firmly establish that the motor system not only causes motor actions but also the feeling of will for those actions. Experiment 1 failed to replicate Haggard and Eimer's principal finding of a within-subject correlation between LRP onset and W. In total, we conducted six within-subject tests of this correlation, and all six failed. We also conducted six between-subject tests and found a significant correlation in only one of them. However, between-subject effects can arise from individual differences such as reaction times and idiosyncratic thresholds for deciding what counts as "W". For these reasons, the within-subject analysis provides a more appropriate test of a temporal correlation between the LRP and W, and no such correlation was found. Thus, the reasoning that Haggard and Eimer used to argue against any causal relation between the RP and W leads us to conclude that there is also no causal relation between the LRP and W.

The conclusion that the LRP does not cause W is consistent with research demonstrating that the feeling of will can be influenced by multiple cues beyond action-intrinsic ones such as efference-copy (Synofzik, Vosgerau, & Lindner, 2009, Wheatley & Looser, 2010). Many empirical studies have demonstrated that cues over which one has no control and that cannot influence action can nonetheless influence the feeling of will for that action (Aarts, & van den Bos, 2011; Desantis, Rousel, & Waszak, 2011; Dijksterhuis & Aarts, 2010; Moore, Lagnado, Deal & Haggard, 2009; Moore, Wegner & Haggard, 2009). In one example, participants reported intention for an action that someone else performed when led to believe that they alone had a consistent (action-related) thought moments before the act occurred (Wegner & Wheatley, 1999). Banks and Isham (2009) showed that the timing of W could be influenced by introducing a deceptive tone that purportedly occurred along with a participant's button press but that actually occurred anywhere from 5 to 60 ms afterward. Lau, Rogers, and Passingham (2007) manipulated the experienced onset of intention using transcranial magnetic stimulation. Most recently, Aarts and van der Bos (2011) demonstrated that the feeling of self-agency for a fixed action can be manipulated by the presence or absence of subliminal primes. In short, several studies have manipulated the feeling of will independently of movement, adding behavioral support for the finding here that the neural antecedents of movement are at least partially independent of the neural antecedents of the feeling of will.

If not conscious will, what do the RP and LRP index? Our Experiments 2 and 3 suggest first that the RP reflects something more general than the neural activity leading to a movement. The go no-go task in Experiment 2 shows that an RP occurs only when participants anticipate that they will move and occurs even if there is a 50% chance that the participant will not initiate a movement. Experiment 3 shows that RP-like potentials occur even when no movement is made and participants are not even preparing to act. There is a difference in the magnitude of these RP-like potentials between task type, which could be explained by differences in the attentional engagement of participants. The RP may reflect general anticipation rather than a preparation or intention to move. Trevena and Miller (2010) made a similar argument by showing that RP-like potentials preceding decisions to move were indistinguishable from those preceding decisions not to move (but see Gomes, 2010). Herrman et al. (2008) found that RP onset occurred before participants could have begun to prepare a specific motor plan and concluded that the RP could not then specifically determine behavior.

In Experiment 2, the LRP did not occur when participants were forewarned about the imperative stimulus (and therefore would presumably have begun to prepare their movement) if the imperative subsequently told them not to move. The LRP occurred only when participants actually moved. The LRP therefore appears to be an indicator of the production of a motor act. This is in line with research showing that the LRP is generated in the primary motor cortex (cf. Eimer 1998; Haggard, 2008). Our data suggest that the LRP, which may indeed signal the initiation of movement, is not temporally yoked to W.

Future research should explore separate components of the LRP, RP, and CNV. While there may be some components of the RP and CNV that are related solely to stimulus anticipation, others may be related to anticipation of movement or preparation for movement (e.g. Schröter & Leuthold, 2008; Van Boxtel & Brunia, 1994). To the extent that the RP and CNV correlate with anticipation rather than motor planning or execution, however, their existence causes problems for Libet's argument that the RP causes movement. Note, however, that we replicated the findings that the LRP is associated with movement and precedes W; this is consistent with a more general view of Libet’s claim that movement-related neural activity precedes W.

It is important to note that the present study only tested awareness as defined by the original Libet and Haggard and Eimer studies. How the feeling of conscious will should be reported and defined is a matter of some debate (Sinnott-Armstrong & Nadel, 2010). Here, we replicated Haggard and Eimer’s (1999) instructions to participants to report “when you first begin to prepare your movement.” However, what is meant by “beginning to prepare” is left to the participant to decide; a decision that necessarily introduces subjectivity and inter-participant variability. Within-subjects statistical tests help account for the inter-participant variability but the inherent subjectivity in defining W remains. Subjectivity-related timing concerns are particularly difficult to avoid under the assumption that W (however defined) is not a directly-accessible event but an inferential process (Dijksterhuis & Aarts, 2010; Wegner, 2002).

Conclusion

Our data do not support the existence of a causal relationship between either the RP or LRP and W, even though both the RP and LRP precede W, as shown by Libet (1983). Neither the RP nor LRP appears to be a correlate of consciousness or volition. The RP may instead be a correlate of general anticipation or preparation, and the LRP a correlate of the activation of a motor strip command to move particular muscles. However, more work is needed to further disentangle the processes of preparation, anticipation, awareness, and volition and to determine how each may relate to the RP and LRP as well

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as the CNV. The classic results of Libet and Haggard and Eimer, as well as many recent discussions of free will and the causal roles of will and of consciousness, will need to be rethought in terms of these findings.

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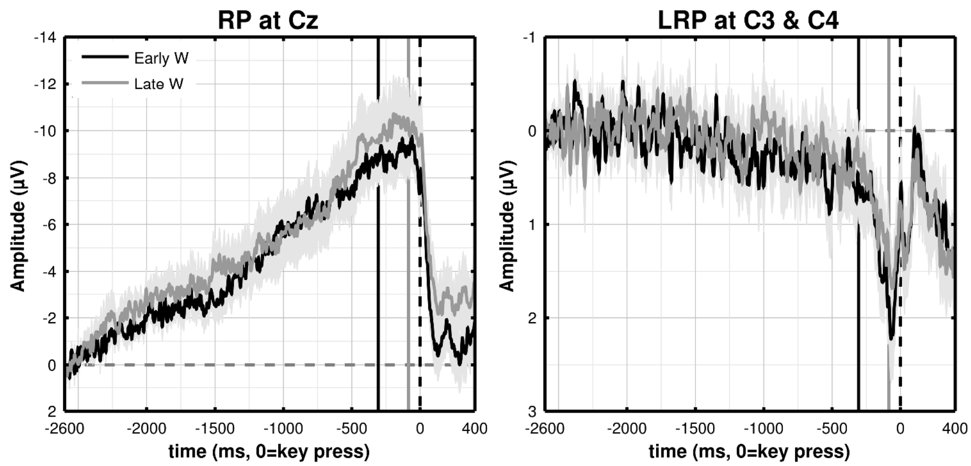

Figure 1. No significant differences exist between early and late awareness RPs at Cz or LRPs at C3 and C4. Solid black vertical line is the mean early W time (-307 ms). Solid gray vertical line is the mean late W time (-85.5 ms). Dotted black vertical line is the time of button press.

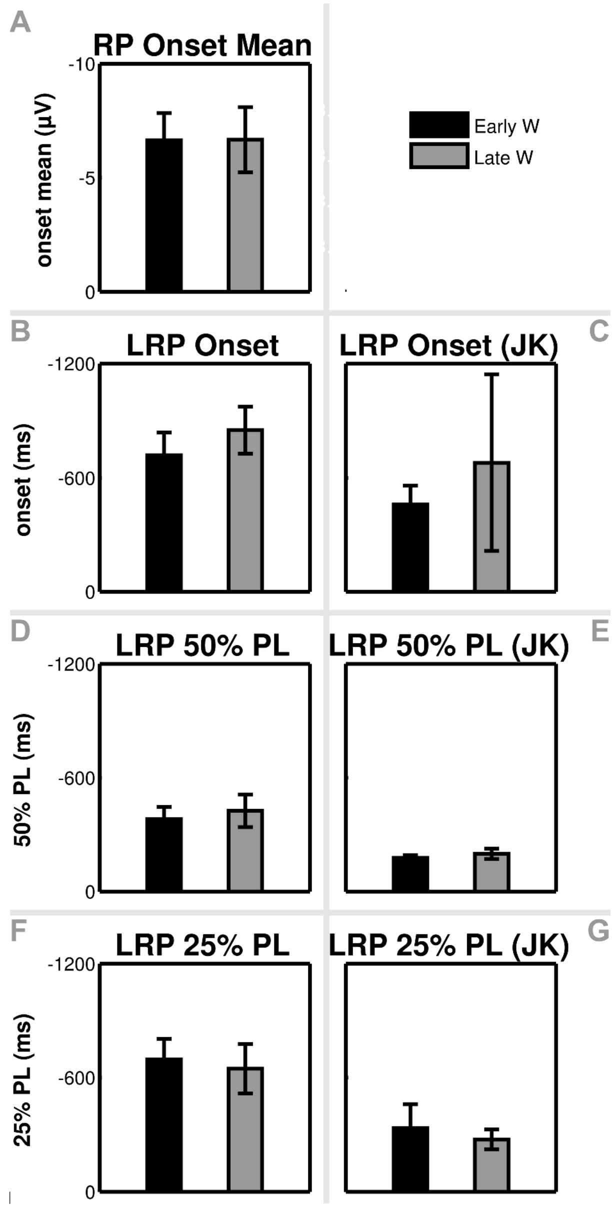

Figure 2. Summary of within-subject t-tests comparing early and late awareness trials. Error bars indicate standard errors of the mean. C, E, and G are jackknifed versions of B, D, and F. A. Mean RP amplitude from -1000 ms to -500 ms before key press. B. LRP onset as measured in Haggard and Eimer (1999). D. 50% peak latency of LRP. F. 25% peak latency of LRP. No differences reach significance.

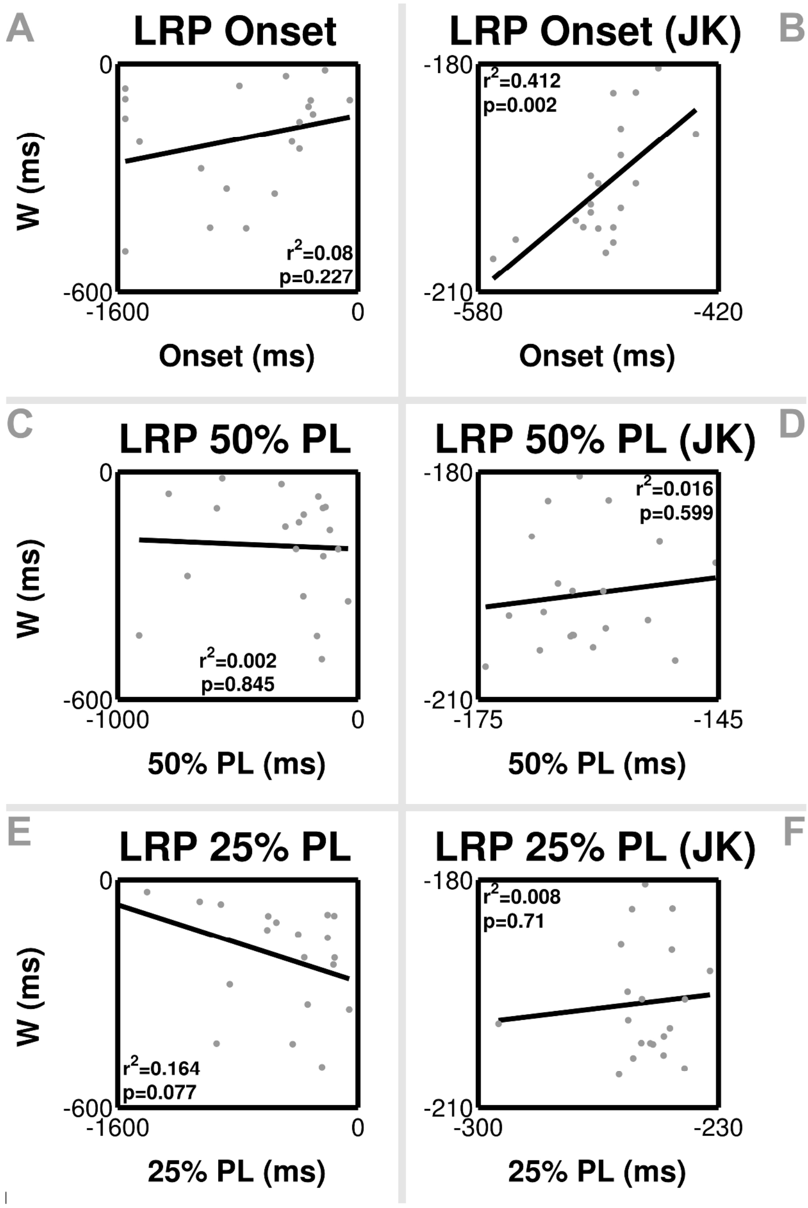

Figure 3. Between-subject correlations of LRP onset and W. B, D, and F are jackknifed versions of A, C, and E. A. LRP onset as measured in Haggard and Eimer (1999). C. 50% peak latency of LRP. E. 25% peak latency of LRP. Only the jackknifed LRP Onset vs. W is significant. 25% peak latency of LRP shows a near-significant inverse correlation with W.

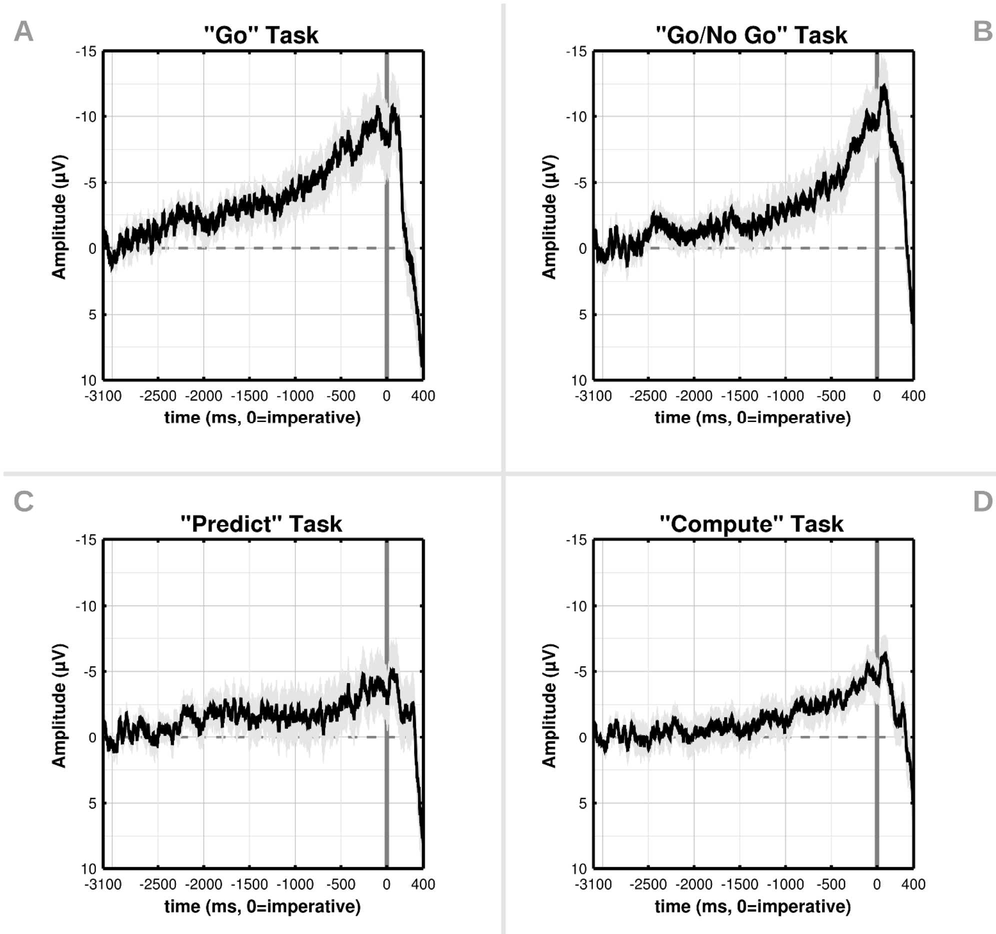

Figure 4. A. Comparison of RPs before movement with and without a warning 3 seconds before the imperative stimulus. Gray vertical dashed line is the mean imperative stimulus time. Black vertical dashed line is time of key press. The RP occurred only when the participant was forewarned of imperative stimulus time. B. The LRP occurred whether or not the participant was forewarned. C. Comparison of RP when a warning stimulus precedes a prompt to either move ("go") or not move ("no-go"). For the "no-go" condition, data are time-locked to the imperative stimulus and shifted to the right by the mean reaction time in "go" trials. The RP occurred whether or not movement occurred. D. The LRP only occurred if movement occurred.

Table 1. Summary of analyses

T-test	early	late	t	p
RP onset mean	-6.65 µV	-6.68 µV	0.0330	0.974
LRP onset	-719 ms	-851 ms	0.857	0.799
LRP onset (jackknife)	-460	-679	0.448	0.670
LRP 50% peak latency	-383	-426	0.409	0.656
LRP 50% peak latency (jackknife)	-179	-200	0.740	0.766
LRP 25% peak latency	-695	-647	-0.386	0.352
LRP 25% peak latency (jackknife)	-335	-275	-0.408	0.344

Correlation		r	r^2	p
LRP onset vs. W	-	0.283	0.0801	0.227
LRP onset vs. W (jackknife)	-	0.642	0.412	0.00230
LRP 50% peak latency vs. W	-	-0.0468	0.00220	0.845
LRP 50% peak latency vs. W (jackknife)	-	0.125	0.0157	0.599
LRP 25% peak latency vs. W	-	-0.404	0.164	0.0770
LRP 25% peak latency vs. W (jackknife)	-	0.0888	0.00789	0.710