NEUROSCIENCE of Consciousness

Neuroscience of Consciousness, 2017, 1–9

doi: 10.1093/nc/nix002
Research article

Deliberation period during easy and difficult decisions: re-examining Libet's "veto" window in a more ecologically valid framework

Eve A. Isham*, Krystal A. Wulf, Camille Mejia and Lara C. Krisst

UC Davis Department of Psychology, Center for Mind and Brain

*Corresponding address: UC Davis Department of Psychology, Center for Mind and Brain, E-mail: eaisham@ucdavis.edu

Abstract

Whether consciousness plays a causal role in cognitive processing remains debated. According to Benjamin Libet, consciousness is needed to deliberate and veto an action that is initiated unconsciously. Libet offered that the deliberation window takes place between the time of conscious intent (W) and action (MR). We further examined this deliberation–veto hypothesis by measuring the length of the temporal window (W-MR) when making easy and difficult choices. If Libet were correct that the W-MR is intended for evaluation and cancelation, we should expect a shorter W-MR for an easy decision since less deliberation is presumably needed. Instead, we observed a less intuitive effect: The W-MR window in the easy trials was longer than the W-MR window in the difficult ones. Our results suggest several interpretations including the idea that consciousness may play a causal role in decision making but not in a straightforward manner as assumed by Libet's veto hypothesis.

Key words: Libet; veto; decision making; decisional complexity; agency; intention; volition; consciousness

The duration between the moment of intent and the time of action is necessary to deliberate and plan an action. Judicial affairs may also rely partially on this temporal window to determine whether a criminal act is premeditated by considering whether there is sufficient time to think and carry out the action. Depending on the nature of the action, this deliberation window could range from seconds to months and years. Importantly, if the duration is determined to be sufficient for deliberation, the action is considered premeditated, and the degree of punishment is determined accordingly. In this manner, it is assumed that consciousness has a causal role toward the production of actions. Yet measuring intention in a laboratory setting and understanding its causal role in action remain challenging.

One obstacle in measuring intention is due in part to the difficulties in determining this private and subjective experience of intent. Subsequently, this makes it challenging to systematically examine the role of this time window. One of the earliest attempts to scientifically mark the timing of intent was carried out by Benjamin Libet and colleagues (Libet *et al.*, 1983). In their experiment, participants were asked to perform a simple wrist flexion and verbally indicate the moment when they first became aware of the decision to do so. Libet called this time of intent to act "W" for will (and assumed it was to be the onset of conscious awareness). This time W was then temporally mapped in reference to the actual time of motor execution. The authors observed W to precede the motor response (MR) by 200 ms, and both moments were preceded by the readiness potential, brain activity involved in the initiation and preparation of motor acts (Kornhuber and Deecke, 1965). Many in the field have interpreted this to mean that actions are unconsciously initiated rather than by a conscious thought or desire to act (e.g. Fried *et al.*, 2011; Soon *et al.*, 2008). This in turn suggests that the conscious experience of intent is simply an illusion and does not have a causal role (e.g. Wegner, 2004). However, Libet's

Submitted: 6 September 2016; **Revised (in revised form):** 23 January 2017. **Accepted:** 26 January 2017

method and results are controversial and the interpretation remains debatable. Several thinkers have cautioned that the Libet task might not efficiently address the causal question due to a range of concerns, including its ecological validity [e.g. Breitmeyer, 1985; See open peer commentary in Libet (1985)], movement-related perceptual biases in the clock used for W (e.g. Joordens *et al.*, 2002), and reliability of the W report (e.g. Banks and Isham, 2009).

In response to the interpretation that free will is epiphenomenal, Libet (1985) offered an alternative view: He postulated that the conscious window between time W and the motor response (henceforth, W-MR) is essential for free will to make the ultimate decision of whether to continue with the action in progress or to cancel it. The hypothesized purpose of the W-MR window thus implies that consciousness has a causal role in the chain of action.

While Libet's research has provided a valuable groundwork toward the empirical understanding of the conscious W-MR window, the hypothesized role as a veto window, however, raises additional questions. One of the concerns is that Libet's wrist flexion task is simple and automatic, resulting in minimal consequences. Such a task requires minimum cognitive resources and therefore is not likely an optimal task to investigate free will and the W-MR as the veto window [e.g. Breitmeyer (1985); See open peer commentary in Libet (1985)]. In life, volition is often associated with a more complex, effortful process. It is unclear from Libet's simple task how the W-MR window might vary with decisions of different degrees of complexity. For instance, would the magnitude of the W-MR window increase with decisional complexity? According to the dual process theory of decision-making, simple decisions are automatic and less deliberative, whereas more difficult decisions require a controlled process and an extended deliberation window (James, 1950; Kahneman and Frederick, 2002; Sloman, 1996; Stanovich and West, 2000; Wason and Evans, 1975). If Libet's deliberation–veto theory holds and the W-MR period serves as the period of deliberation and cancelation, it would follow that an easy decision requires a shorter W-MR compared to a difficult decision. Such evidence would strengthen Libet's claim.

Although efforts have been made to understand the W-MR window (e.g. Caspar and Cleeremans, 2015; Sirigu *et al.*, 2004), some of which involve using higher abstract thought (Soon *et al.*, 2013) and some were ecologically-driven (Schultze-Kraft *et al.*, 2016), to our knowledge, there is no direct assessment of how the W-MR window varies with decisional complexity in a more naturalistic and ecologically valid context. Moreover, some of the related research seems to contradict the predictions made by the deliberation–veto hypothesis. For instance, participants in Haggard and Eimer's (1999) study performed a series of voluntary actions and reported time W in each trial. Via a median split, the authors categorized the W reports from individual subjects either as early or late Ws. On the assumption that Haggard and Eimer's early W is equated to the W of simple and easy decisions, and the late W to the W of complex decisions (Lau *et al.*, 2006), we were interested in seeing if the corresponding W-MR would vary between these two types of W trials. Although the authors did not compute the W-MR based on their data, we were able to do so independently using the values reported in their publication. If consistent with Libet's deliberation–veto hypothesis, W-MR for the early W trials (presumably easy trials) should be shorter since the decision would not require an extensive deliberation. However, this was not the case: the averaged W-MR for the early trials was 530 ms, whereas the W-MR for the late trials (presumably difficult) was significantly shorter, at 179 ms. It is unclear why the gap between W and the motor response was longer in the early intent trials than in the late trials. That is, why would the participants wait longer to actually act even though they had felt intent sooner? These counterintuitive observations thus add to the concern of whether W-MR serves a purpose different from one postulated by Libet.

To better understand the functions of the conscious window W-MR, the current study is aimed to characterize W-MR in a more ecological and systematic fashion. We employed a modified Libet paradigm and measured the W-MR period for simple and complex decisions. As mentioned earlier, Libet's original wrist flexion task is often criticized as nonecological and is inappropriate to addressing the question of free will because it is too simple, even becoming automatic as the experiment progresses. It also does not have any consequences. To address this, the experimental task in the current study was designed so that the participants needed to deliberate, and that their decisions varied in degree of complexity and consequences. In this manner, the evaluation of the W-MR characteristics would be made in reference to more realistic decisions, and we believe our experiment is a step closer toward ecological validity.

Based on the decision-making literature (e.g. Kahneman and Frederick, 2002; Sloman, 1996; Stanovich and West, 2000; Wason and Evans, 1975), we anticipated a shorter W-MR period associated with easy decisions, and longer W-MR period with difficult decisions. This in turn would strengthen the support for the decisional hypothesis that the W-MR period has a causal role in action. On the other hand, if the manner in which W-MR varied with decisional complexity deviated from those predicted by the decision-making literature, it would suggest that the purpose of the W-MR window in decision-making might not be as straightforward as predicted by the deliberation–veto hypothesis. Alternatively, this same unexpected result could also resonate, at least partially, with nondecisional cognitive processes. For example, W-MR might be a byproduct of inaccurate introspection [e.g. Banks and Isham (2009), suggested that the decision time W is not directly perceived, but retrospectively inferred from the perceived timing of action]. An inaccurate or biased W would raise the question of whether Libet's W-MR is the true conscious veto window. Subsequently, this leads to the question of whether consciousness has any causal role toward action execution.

Experiment 1

Participants performed a modified Libet paradigm that involved making decisions of different degrees of difficulty. The temporal period between intent and decision (W-MR) was measured according to the degree of decisional difficulty.

Method

Participants

Twenty participants were recruited from a pool of undergraduate student volunteers at the University of California, Davis. Six of the twenty anticipated data sets were not included in the remaining analysis due to technical difficulties or early withdrawal. Of the remaining 14 participants (13 females, 18–26 years old), subjects were fluent in English. The participants consented to the study protocol which followed the guidelines approved by the Institutional Review Board of the University of California, Davis.

Materials and procedure

Each participant was placed at a computer screen and was instructed to listen to a series of statements (samples of stimuli in Appendix 1). The statements were created to have a varying degree of consequences which presumably would render in a varying degree of decision difficulty (e.g. a decision to the statement "I like red more than blue" was assumed to have less consequences and would result in a low difficulty rating. A decision to the statement "To save a village, it's okay to sacrifice a child" would be of greater consequences, and would result in a high difficulty rating). In addition, we also selected the statements that had no absolute or correct answers to ensure the perception for the freedom of choice. Finally, some of the statements were inspired by current events in our community that were relatable to our subject population. For instance, "Plastic bags should be banned" was a controversial topic in our community at the time of our experiment. The statement sound files were spoken by a female speaker and were recorded by Audacity software (1999). The averaged statement length was 3037.61 ms. The statements were randomized and serially presented using Superlab (Cedrus Corporation, San Pedro, CA).

While each statement was being presented auditorily via the computer speakers, an analog circular clock was presented visually on the computer monitor, sharing the same onset time as the statement stimulus. The clock was 10.16 cm in diameter, positioned at the center of the screen, and was viewed from approximately 60 cm. Sixty tick marks were drawn along the circumference; a red dot moved along these tick marks, completing a rotation in 3 s. Each trial concluded at the end of the third clock rotation, lasting 9 s in total trial duration.

Participants were instructed to listen to the statement carefully and to make a decision to agree or disagree with the statement and to indicate their decision by pressing a keyboard key designated as the "Agree" or "Disagree" button. The key assignment was counterbalanced across subjects. The keypress was to occur as soon as the participants knew what their decision was. Participants were also instructed to take a mental note of the position of the red dot on the clock when they felt a decision onset (i.e. "W"). It was emphasized that this was not the time in which they physically pressed the button, but rather the earliest moment in which they became aware of having an inkling toward a decision. At the conclusion of the trial, participants verbally reported this clock value. They also rated the difficulty level of the decision on a Likert scale of 1–5, with "5" being the most difficult.

A total of 10 practice trials and 60 experimental trials were administered.

The procedure is summarized in Fig. 1.

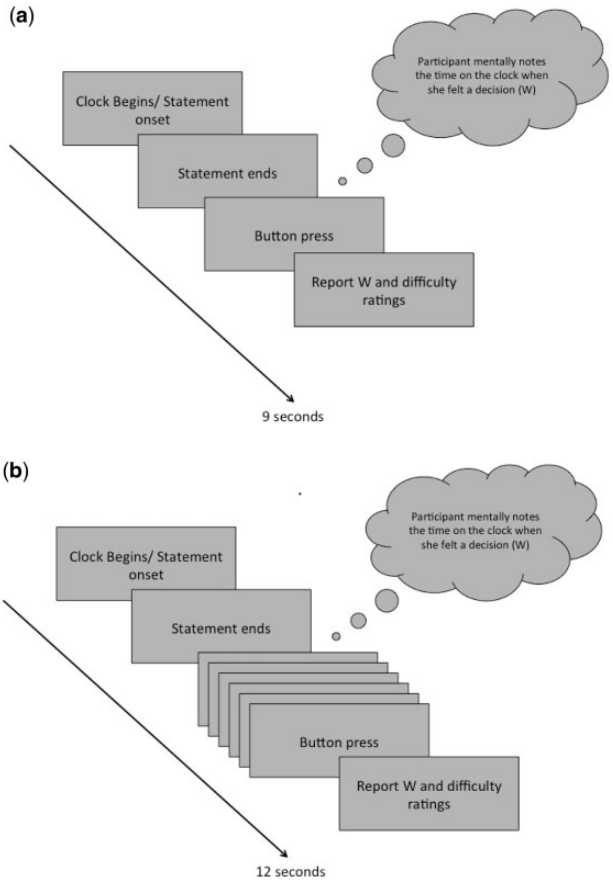

Figure 1. (a) An experimental trial begins with the presentation of a statement stimulus and a running clock. At the end of the statement, participants were to decide whether they agreed with it, and to take a mental note of the time in which they felt a decision onset by reading from the clock. Subsequently, they pressed a decision button to indicate their decision, and verbally reported the time of the decision onset and the difficulty rating. Each trial concluded in 9 s. (b). In Experiment 2, participants also made additional presses to indicate additional thoughts they had after having had a decision onset. Experiment 2 trials concluded in 12 s.

Analyses

Response time

Although traditional response times (RTs) are computed when a motor act is executed, in the current study, we computed RT as the difference between the time in which the statement ended and the moment of decision (W). As in typical cognitive events, an easier task would draw a shorter RT than a difficult task.

W-MR

The time period of W-MR was calculated as the time difference between the moment of decision (W) and the moment of the motor response (MR). This time period reflects the time between the subjective private experience of having an inkling toward a decision and the moment of motor execution.

Difficulty ratings

Participants' ratings were assigned to "easy" and "difficult" categories using a median split.

Results

The temporal relationship between the time of the statement offset, W, and MR are represented in Fig. 2a. The results of the statistical analyses comparing these values according to decisional complexity are described below. Data can be made available upon request.

RT

We first examined the response time as a manipulation check and ensured that RT was shorter for easy decisions than difficult ones. As shown in Fig. 2a, participants made their decision earlier for the easy trials (RT = 2248 ms, SE = 191) than difficult ones (RT = 3554 ms, SE = 277), $t(13) = 5.32$, $\eta^2 = 0.69$, $P < 0.001$. The pattern of results is similar to previous work in decision-making literature that has explored higher thought decision-

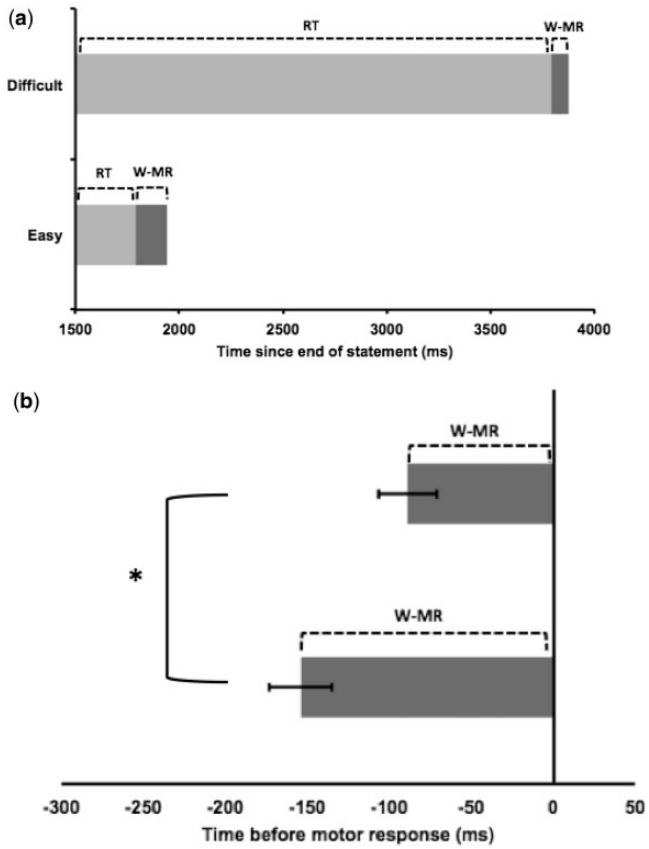

Figure 2. (a) Timing of decision (W) and motor response (MR) relative to statement offset (time 0; not shown on graph). On each bar, the gray portion represents the time lapse between statement offset and W (i.e. response time), and the black portion represents the time window between W and MR. Participants experienced a decisional inkling sooner in the easy trials (shorter RT), but waited longer to actually press the button in the easy trials (longer W-MR) compared to the difficult trials. (b) Timing of decision (W) relative to the motor response (time 0). Compared to the difficult trials, participants experienced a decisional inkling sooner but waited longer before pressing the button, resulting in a longer W-MR window in the easy trials compared to the difficult trials.

making (e.g. Krajbich *et al.*, 2010). Therefore, the RT data serve as validation of our manipulation of easy and difficult decisions.

W-MR as a function of difficulty ratings

We anticipated W-MR to be longer in the difficult trials. Unexpectedly, we observed the opposite: a longer W-MR interval for easy decisions (154 ms, SE = 19) than for difficult ones (99 ms, SE = 18), $t(13) = 2.402$, $\eta^2 = 0.31$, $P < 0.04$ two-tailed (Fig. 2b).

Discussion

The purpose of Experiment 1 was to characterize W-MR in a more ecological context. Based on Libet's deliberation–veto hypothesis, we anticipated a shorter W-MR period associated with easy decisions, and longer W-MR period with difficult decisions. However, we observed the opposite: Easy trials were associated with longer W-MR and difficult trials were associated with shorter W-MR. The results are similar to those reported by Haggard and Eimer's work (1999). In their study, the averaged W-MR in the early W judgment trial was also longer (530 ms) than the W-MR in the late W judgment trials (179 ms). The converging patterns of results from their study and the current study leads to the question of whether the W-MR serves as a deliberation and vetoing window as previously proposed by Libet.

There are several theories that could shed light on our findings, leading to several different possible interpretations. Initially, the data, being the opposite of what was predicted by the deliberation–veto hypothesis, seemed to suggest that the W-MR period was not related to the process of deliberation. After further examination, it is possible that W-MR is involved in the process but not in a straightforward manner as proposed by Libet. Again, if the W-MR window were to serve an evaluation and cancelation purpose, there should be less deliberation in the easy decisions. Based on our findings, we propose, instead, that the results resonate with two distinct decision-making approaches for easy and difficult choices. Post interviews suggest that participants felt they reached an easy decision rapidly but spent additional time to reevaluate the decision. This is consistent with the dual process theory in the decision-making literature in which easy decisions are automatic and intuitive, whereas difficult decisions are more deliberative and controlled (e.g. James, 1950; Kahneman and Frederick, 2002; Sloman, 1996). In the easy decisions trials, participants are likely to arrive at the decision with ease, and then rely on the W-MR window to reevaluate these automatic decisions. In the difficult trials, participants are more actively engaged in the deliberation "before" having an inkling toward a decision. In this manner, consciousness is needed for action but consciousness actually begins outside of the Libet's defined W-MR window.

Alternatively, the results from the current experiment could be attributed to other nondecisional factors, namely time constraint. Due to the fact that there was a time limit (i.e. each trial ended in 9 s), it was possible that the clock time was not sufficient to extensively deliberate on difficult decisions. The participants could have felt the time pressure to produce a motor response before time ran out, resulting in a compressed temporal window between time W and MR in the difficult trials (see Experiment 2).

Experiment 2

Based on the results from Experiment 1, the purpose of Experiment 2 was to examine whether more active evaluation is engaged during the W-MR period in the easy trials. In addition, the experiment was also designed to test whether the effect observed in Experiment 1 could be attributed to time constraint.

Method

Participants

A different set of 20 participants was recruited from a pool of research volunteers at the University of California, Davis. Of these, one participant was unable to follow directions and his data were excluded from the analysis. All participants were fluent English speakers. The protocol followed guidelines approved by the Institutional Review Board of the University of California, Davis.

Materials and procedure

The participants were presented with a new series of statement stimuli to ensure that the effect was not specific to the stimuli used in Experiment 1 (samples of stimuli in Appendix 2). Upon the stimulus presentation, the participants were asked to take a mental note of the time of their initial decision (W) by reading the time from the analog clock as well as to rate the level of difficulty. In addition to this procedure, several modifications were also made to address some of the concerns as followed:

To investigate whether re-deliberation was more likely during the W-MR interval of an easy decision, we asked the participants to continue to press a decision button as often as they were aware of a new thought related to the statement, and to do so until satisfied. They were allowed to switch between the AGREE and DISAGREE button throughout the trial. In this manner, the frequency of thoughts as well as the frequency of mind changing would be used as possible markers for deliberation.

In addition, to address the concern regarding time limit, we extended each trial to 12 s (i.e. 4 rotations of the clock). After each trial, we also asked the participants to indicate whether they could have used more time to make a decision. If more time was needed, the trial was excluded from the analysis. Figure 1b summarizes the Experiment 2 procedure.

Results

The temporal relationship between the time of the statement offset, W, and MR are represented in Fig. 3a. The results of the statistical analyses comparing these values according to decisional complexity are described below. Data are available upon request.

Limited time

We first identified and excluded the trials in which participants reported to have needed more time. For the easy decisions, one participant reported needing more time on 1.7% of the easy trials. For the difficult decisions, six participants reported needing more time. The averaged number of difficult trials that were excluded for these individuals was 16.7%.

Time taken to complete a trial

After the exclusion of limited-time trials, the remaining trials were examined whether the last press occurred within the trial period. Overall, as expected, we observed that difficult decisions (10.25 s, SE = 0.19) took longer than the easy ones (9.86 s, SE = 0.26), $t(18) = 2.24$, $\eta^2 = 0.22$, $P = 0.038$ two-tailed. Importantly, we observed that despite the longer decision making interval for difficult decisions, the completion time did not exceed the trial period; that is, the difficult decisions were made well in advance of when the 12-s trial period ended, $t(18) = 9.38$, $P < 0.001$.

RT

Consistent with Experiment 1, the response time for easy trials (RT = 3921 ms, SE = 111) was earlier than difficult ones (RT = 4873 ms, SE = 218), $t(18) = 6.38$, $\eta^2 = 0.69$, $P < 0.001$; see Fig. 3a. The results satisfied the manipulation check.

W-MR

One of the primary goals was to replicate the findings in Experiment 1. With a new set of statement stimuli, we continued to observe longer interval W-MR for easy decisions (194.28 ms, SE = 43.34) than the W-MR for difficult decisions (41.06 ms, SE = 59.11), $t(18) = 2.67$, $\eta^2 = 0.28$, $P = 0.016$ two-tailed. Given that the analyzed data were drawn from trials with sufficient decision-making time, the phenomenon, thus, is not reflective of insufficient time resource. W-MR data are represented in Fig. 3b.

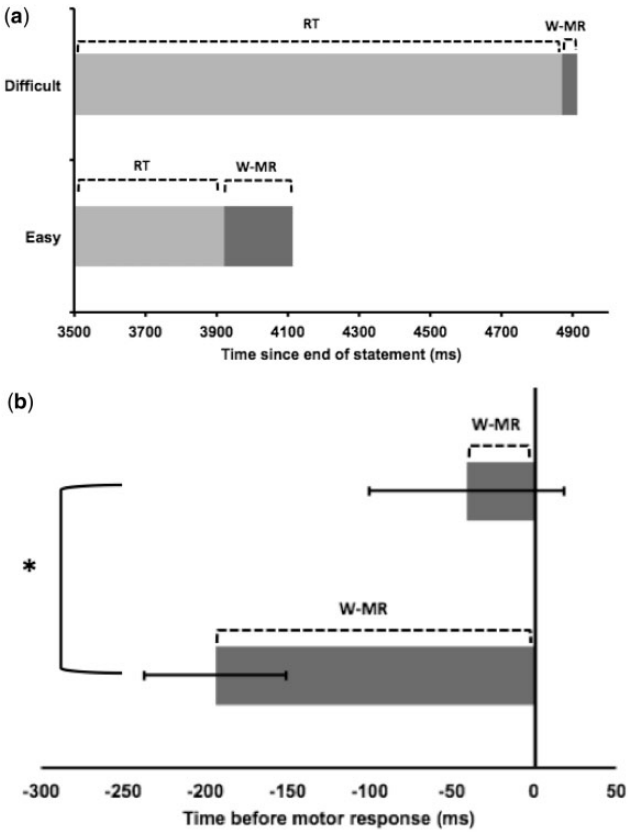

Figure 3. (a) Timing of decision (W) and motor response (MR) relative to statement offset (time 0; not shown on graph). As in Experiment 1, the gray portion of each bar represents the time lapse between statement offset and W (i.e. response time), and the black portion represents the time window between W and MR. In agreement with Experiment 1, participants experienced a decisional inkling sooner in the easy trials (shorter RT), but waited longer to actually press the button in the easy trials (longer W-MR) compared to the difficult trials. (b) Timing of decision (W) relative to the motor response (time 0). Compared to the difficult trials, participants experienced a decisional inkling sooner but waited longer before pressing the button, resulting in a longer W-MR window in the easy trials compared to the difficult trials.

Frequency of thoughts

It is possible that simple, easy decision-making is an automatic process that occurs prior to conscious awareness. Once the completed decision enters consciousness, the observer goes through a process of verification to confirm the decision. A more complex decision, on the other hand, must first enter consciousness to be deliberated, and then a decision is made. To explore this hypothesis, we compared the frequency of thoughts during the W-MR interval. If the verification hypothesis were to be supported, we would expect to see a greater frequency of thoughts during the W-MR period of the easy trials as a reflection of the re-evaluation process. In addition, the converse of this hypothesis suggests that the deliberation of difficult decisions precedes the W-MR window instead of within it. Thus, less thinking and fewer thoughts are expected to appear during

the W-MR window of difficult trials. The data were trending in this direction, but not statistically reliable: the frequency of thoughts for easy (4.66 keypresses, SE = 0.50) was not different from the frequency of thoughts for difficult decisions (4.21 keypresses, SE = 0.60), $t(18) = 1.58$, $\eta^2 = 0.12$, $P > 0.10$. Given the lack of significance we computed a Bayes factor (Dienes, 2014) to test for sensitivity. We observed a Bayes factor of 0.29, supporting the null hypothesis.

Mind changing rate

Mind changing rate was calculated by assigning a "1" to the trial if at least one of the button presses was different from the others, and a "0" if all the button presses were the same. We observed a higher mind changing rate for the difficult decisions (0.25, SE = 0.29) than for the easy decisions (0.04, SE = 0.01), $t(18) = 7.54$, $\eta^2 = 0.76$, $P < 0.001$, two-tailed.

Discussion

One of the purposes of the current experiment was to reproduce the effect observed in Experiment 1 but under less rigid temporal constraints and with a new set of stimuli. Having extended the time and excluded trials in which participants felt a temporal constraint, we continued to observe a longer W-MR for easy trials than difficult ones. This replication of Experiment 1 thus rules out time constraints as a contributing factor to the effect.

Given the replication, the critical question remains: why is the delay between the time of intent and the time of motor response longer in the easy trials compared to the difficult trials. As discussed in Experiment 1, this could reflect the different roles of the W-MR window during easy and difficult decisions. One speculation is that easy decisions are made automatically, but requires some post-decision time (i.e. the W-MR window) to reevaluate and confirm the decision. The difficult trials on the other hand require effortful deliberation before the decision is reached, and therefore does not need a post-decision window (W-MR) for further deliberation. We approached this hypothesis by quantifying the frequency of thoughts. However, the variable was not statistically different between easy and difficult trials, leaving the need for a different approach to test the hypothesis. We elaborate on this and other alternative hypotheses in the General Discussion section.

General Discussion

The current study examined the possible functions of the W-MR window formerly introduced by Libet (1985) as the veto window. We asked how the length of the W-MR might vary with decisional difficulty as this could provide further insights into the purpose of the W-MR period. Based on Libet's veto hypothesis, and in conjunction with the dual-process theory of decision-making, we anticipated the W-MR window to be longer for more complex or difficult choices since greater deliberation would be needed. However, our results were the opposite of this prediction. We found that the W-MR window was longer in the easy trials than in the difficult trials (similar to Haggard and Eimer's, 1999 results for early and late W). If the results were to support the simple veto hypothesis, we would have seen a shorter W-MR window for easy than for difficult trials since less time should be needed for simple deliberation. The opposite observation suggests that the purpose of the conscious W-MR window is not as straightforward as previously assumed by the deliberation–veto theory and that it might vary with decisional difficulty: Our findings suggest that we need a longer W-MR to reevaluate unconsciously initiated decisions than in the consciously engaging difficult trials (see Point I for further discussion).

We offer below points of discussion and possible theories and interpretations of the findings. Point I discusses the possibility that W-MR serves different purposes for easy and difficult decisions. This has also been the focal point of Experiment 2. Point II focuses on the complexity of the experimental task, leading to a competition of cognitive resources and a delayed W report in the difficult trials. Finally, Point III speculates on the different manners in which W reports could be generated and how each could contribute to the W-MR window. These points of discussion are hopeful as the basis for building future investigations to determine the underlying mechanisms of the W-MR effect reported here. Subsequently, the knowledge gained from the current and future studies may help better our understanding of the mechanisms underlying the W-MR window, and possibly help shed light on the function of consciousness.

I. W-MR serves different purposes for easy and difficult decisions

The W-MR window is defined as the period between the perceived moment of intent and the moment of the corresponding motor response. This temporal window, according to Libet (1985), is when we consciously evaluate and cancel an action, if desired. Based on our results, however, it seems that easy decisions, but not difficult ones, behave in a manner that is consistent with Libet's hypothesis. In the easy trials, the W-MR period was longer than the W-MR for difficult trials. On this interpretation, we speculate that easy decisions are completed faster, but a post-decision reevaluation is needed during the W-MR period to monitor the decision. However, such interpretation does not apply to the results observed in the difficult trials. In these trials, the W-MR window is significantly shorter compared to the W-MR window for the easy trials, leading to the interpretation that the deliberation process occurs prior to the W-MR period and therefore less time is needed to verify the decision that has already been consciously made.

These interpretations are corroborated by previous literature, along with post-experiment interviews and the results from Experiment 2. From the literature, it has been suggested that a more complex decision must first enter consciousness (Soon *et al.*, 2008, 2013) for deliberation, and subsequently a decision is made, and the corresponding motor act is executed. From the post-experiment interviews in the current study, some participants reported that decisions in the easy trials came almost immediately that they felt the need to reevaluate the choice before pressing the button to indicate their final decision. On the other hand, the participants felt that a more effortful reasoning took place "prior" to experiencing intent (i.e. time W) in the difficult trials, leaving a minimal need for further deliberation in the defined W-MR window. Moreover, in Experiment 2, the frequency of thoughts was higher during the W-MR period of the easy trials than in the difficult ones, corroborating with the participants' reports.

Based on the observed results and within the Point I discussion, we speculate two explanations as to why W-MR is non-intuitively longer in the easy trials than in the difficult trials. First, it is possible that the W-MR period serves different functions for different decisional complexity. At the easy level, W-MR serves as the deliberation–veto window consistent with Libet's hypothesis. At the difficult level, W-MR plays a minimal

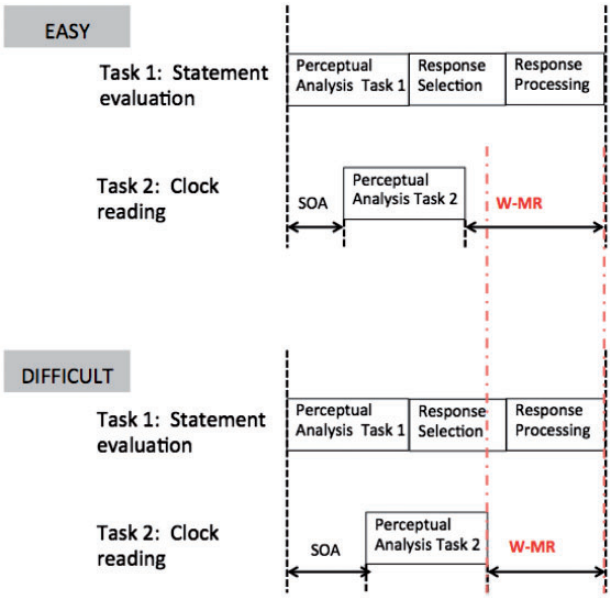

Figure 4. Dual-task may effectively influence the W-MR window. In a difficult trial, clock reading (Task 2) may be delayed [i.e. longer stimulus onset asynchrony (SOA)], resulting in a late W report and a shorter W-MR.

role since deliberation would have already occurred prior to time W. In addition to the first explanation, one could also argue that this is due to the operational definition of W. Again, W is defined as the earliest moment in which the agent becomes aware of a decision. For a difficult decision, conscious deliberation must occur "before" reaching time W, leaving little need for further deliberation in the W-MR window. Thus, the W-MR window of the difficult trials may serve primarily as a period for planning and executing a corresponding motor response to the decision rather than as a period of deliberation of the decision itself. One possible way to test for this would be to ask the participants to indicate when they are aware of the meaning of the statement (let us call it "A"). Presumably, when one becomes aware of the meaning of the sentence, the conscious and active deliberation begins. We then would expect A to precede W. The time gap between A and W is expected to be longer in difficult trials than in the easy trials. If this were the case, it would imply that consciousness has begun outside of the W-MR window (as how W-MR is defined by Libet).

II. Task demand

Another possible explanation for the W-MR effect observed in our study may be due to a task-related cognitive demand. A clock-based intention-measuring task, like the one used in the current study, is relatively complex. While having to process the clock visually, participants also were asked to process the statements auditorily and at a meaningful level. Given the task, there could be two mental operations (dual task) competing simultaneously for cognitive resources; i.e., when making a decision and executing the corresponding manual response about a statement (Task 1), and when reading and mentally marking the time on the clock (Task 2). Especially in the difficult trials, such competition could potentially delay the clock reading of W, therefore creating an unintended latency between the processing of the statement and the clock [i.e. increased stimulus onset asynchrony (SOA)]. In turn, delayed clock reading results in later W report, and subsequently a shorter W-MR window for difficult trials (Fig. 4). This speculation is in parallel with the psychological refractory period seen in dual task paradigms (e.g. Pashler, 1994). Matsuhashi and Hallet (2008) touched on this possibility when using the Libet clock and have proposed a different way to measure W.

To address this concern, a future study could minimize the involvement of clock reading and see if the W-MR period continues to vary with easy and difficult tasks. If clock removal minimized the effect of decisional difficulty on the W-MR window, it would mean that the observed W-MR effect in the current study is a byproduct of task demand, and therefore the W-MR window does not have a causal role.

III. How is W generated?

A third possible explanation for the observed W-MR period focuses on the origin of W itself. That is, W-MR period could hypothetically be dictated by how, and when, W is experienced and reported. The reporting of W itself could be thought of as a decision-making process in which one must reach a certain threshold or criterion to commit to a W value (drift diffusion model; e.g. Busemeyer and Rapoport, 1988; Ratcliff and McKoon, 2008). Imagine a case in which the decision to commit to W is quick in the easy trials and slow in the difficult trials. Given a fixed time to complete the motor response, the faster W drift rate in the easy trials would result in committing to an early W that precedes the completion of the corresponding motor response far in advance. On the other hand, the drift rate of a W in the difficult trials is slow, resulting in a late commitment of W that precedes only slightly before the time of the motor response (Timothy Hanks, personal communication, August 2016; see also "variable rate model," Hanes and Schall, 1996). In this manner, commitment to a W value is the source that dictates the size of the W-MR temporal window.

In addition to the drift diffusion model, it has been shown that the moment of intent (W) could be inferred. For example, Banks and Isham (2009) showed that the moment of W was inferred from the presumed time of action. Others have also shown the influence of contextual information on other forms of subjective time reports (e.g. Haggard *et al.*, 2002; Isham *et al.*, 2011; Isham and Geng, 2011; Stetson *et al.*, 2005; Wegner and Wheatley, 1999). Thus, it is possible that W could vary with presumed decisional characteristics (e.g. if a decision is felt as easy, W is perceived as earlier). This in turn would suggest that the W-MR period does not serve the deliberation purposes and therefore implies a non-causal role of consciousness toward action production.

Another possible explanation why the W-MR window is more compressed in the difficult choices might be related to agency. Past studies on intentional binding (Haggard *et al.*, 2002) suggest that volition and agency modify the perceived time of action and the time of a tone response. Wenke and Haggard (2009) extended this line of research by examining the binding effect in active (participants depressed a key with their finger; such action enhances a sense of agency) and passive actions (a servo motor pushed down the finger that in turn depressed the key; limited sense of agency). The results show greater time compression between the perceived time of action and the perceived time of the tone response in the active condition than in the passive condition. This implies that an increased sense of agency results in a shorter perceived time interval between action initiation and its resulting effect (e.g. a tone). Such results could also be mapped onto the current findings: Making an effortful decision in our

study would be in parallel with an active action that possesses a strong sense of agency. In turn, this greater sense of volition associated with the difficult decisions could elicit a stronger form of temporal binding between the perceived time of intent (W) and the time of the motor response.

Future Directions

The current study is a step toward the understanding of the W-MR window. In addition to the possible explanations offered above, future investigation might also benefit from other experimental modifications. For instance, a future study could allow for an unlimited time to make a decision. In such manner, there could be an increase in the perception of volition, and the results from such paradigm could speak more directly to the question of free will. Moreover, a new task could include the option to explicitly veto (withhold) a decision. Although the current study had allowed the participants to change their mind (Experiment 2), they still had to complete a motor response for the initial decision rather than withholding it. Brass and Haggard (2008) described three decision components of intentional action: what, when, and whether. The what component is related to which action of the available alternatives to execute (e.g. in our case, to agree or disagree). The when component reflects the decision of when to perform an action (e.g. in our case, to press the button corresponding to the decision in the what component). The whether component is related to the decision of whether to execute an action or not (e.g. when asked to cancel an action in a Libet-type paradigm, or in a go/no-go task). Based on this model, the whether component is not present in our study. In a future investigation, by asking participants to withhold their decision we could speak more directly to Libet's veto hypothesis.

In addition, it might be worthwhile to assess the deliberative process more rigorously from a first-person perspective. For instance, a future study could ask the participants to speak their thoughts out loud as they begin the deliberative process. Moreover, a structured post-experiment interview that directly assesses when the participants reach a decision and whether they deliberate before and/or after the decision would also be another approach toward verification of the hypothesis that reevaluation and deliberation are associated with easy and difficult decisions, respectively.

Final Remarks

We report here a reproducible phenomenon relating the W-MR window to decisional complexity. We found the W-MR window to be shorter in the difficult trials and longer in the easy trials. Although the underlying mechanisms are currently unknown, our study raises questions about the temporal window of consciousness, and the function of Libet's veto window. We have suggested possible factors to be investigated in future studies. Once the underlying mechanisms are identified, this time window could help answer the question of whether consciousness has a function.

Acknowledgements

The authors would like to thank Arne Ekstrom, Joy Geng, Bill Prinzmetal, Timothy Hanks, Michael Pitts, and Bruce Bridgeman for valuable feedback on an earlier version of the article. The author would also like to thank Fernanda Cazares for her contribution to the statement stimuli, Cong-Huy Le, Mellissa Villacarte, and Tiffany Wall for their help with data collection, Ellyn Daly for her editorial assistance, and Sam Mosher for technical assistance. We greatly appreciate the thoughtful and insightful comments from the reviewers on an earlier version of the article. Authors' contribution: E.A.I. and K.A.W. developed the study concept and the study design. K.A.W. and C.M. performed data collection and analysis under the supervision of E.A.I. All authors contributed to the interpretation of the data and approved the final version of the article for submission.

Funding

The project was supported by the New Agendas for the Study of Time (funded by the Templeton World Charity Foundation) and by the UC Davis Center for Educational Effectiveness.

Conflict of interest statement. None declared.

References

Audacity [Computer software]. (1999). Retrieved from http://www.audacityteam.org/

Banks WP, Isham EA. We infer rather than perceive the moment we decided to act. *Psychol Sci* 2009;**20**:17–21.

Brass M, Haggard P. The what, when, whether model of intentional action. *Neuroscientist* 2008;**14**:319–25.

Breitmeyer BG. Problems with the psychophysics of intention. *Behav Brain Sci* 1985;**8**:529–66.

Busemeyer JR, Rapoport A. Psychological models of deferred decision making. *J Math Psychol* 1988;**32**:91–134.

Caspar EA, Cleeremans A. "Free will": are we all equal? A dynamical perspective of the conscious intention to move. *Neurosci Conscious* 2015;**1**:niv 009.

Dienes, Z. Using Bayes to get the most out of non-significant results. Frontiers in Psychology 2014. https://doi.org/10.3389/fpsyg.2014.00781

Fried I, Mukamel R, Kreiman G. Internally generated preactivation of single neurons in human medial frontal cortex predicts volition. *Neuron* 2011;**69**:548–62.

Hanes DP, Schall JD. Neural control of voluntary movement initiation. *Science* 1996;**274**:427–30.

Haggard P, Clark S, Kalogeras J. Voluntary action and conscious awareness. *Nat Neurosci* 2002;**5**:382–5.

Haggard P, Eimer M. On the relation between brain potentials and the awareness of voluntary movements. *Exp Brain Res* 1999;**126**:128–33.

Hundrieser M, Stahl J. How attitude strength and information influence moral decision making: Evidence from event-related potentials. *Psychophysiology* 2016;**53**:678–88.

Isham EA, Banks WP, Ekstrom AD, *et al*. Deceived and distorted: game outcome retrospectively determines the reported time of action. *J Exp Psychol Human Percept Perform* 2011;**37**:1458–69.

Isham EA, Geng JJ. Rewarding performance feedback alters reported time of action. *Conscious Cogn* 2011;**20**:1577–85.

James W. *The Principles of Psychology*. New York: Dover, 1950.

Joordens S, van Duijn M, Spalek TM. When timing the mind one should also mind the timing: Biases in the measurement of voluntary actions. *Conscious Cogn* 2002;**11**:231–40.

Kahneman D, Frederick S. Representativeness revisited: attribute substitution in intuitive judgment. In: Gilovich T, Griffin D

and Kahneman D (eds.), *Heuristics and Biases*. New York: Cambridge University Press, 2002, 49–81.
Kornhuber HH, Deecke L. Hirnpotentialanderungen bei Willlcurbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiate. *Pflugers Archiv Fiir Gesamte Physiologie* 1965;**284**:1–17.
Krajbich I, Armel C, Rangel A. Visual fixations and the computation and comparison of value in goal-directed choice. *Nat Neurosci* 2010;**13**:1292–8.
Lau HC, Rogers RD, Passingham RE. On measuring the perceived onsets of spontaneous actions. *J Neurosci* 2006;**5**:7265–71.
Libet B. Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behav Brain Sci* 1985;**8**:529–66.
Libet B, Gleason CA, Wright EW, *et al*. Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). *Brain* 1983;**106**:623–42.
Matsuhashi M, Hallett M. The timing of the conscious intention to move. *Eur J Neurosci* 2008;**28**:2344–51.
Pashler H. Dual-task interference in simple tasks: data and theory. *Psychol Bull* 1994;**116**:220–44.
Ratcliff R, McKoon G. The diffusion model: theory and data for two-choice decision tasks. *Neural Comput* 2008;**20**:873–922.
Schultze-Kraft M, Birman D, Rusconi M, *et al*. The point of no return in vetoing self- initiated movements. *Proc Natl Acad Sci* 2016;**113**:1080–5.
Sirigu A, Daprati E, Clancia S, *et al*. Altered awareness of voluntary action after damage to the parietal cortex. *Nat Neurosci* 2004;**7**:80–84.
Sloman SA. The empirical case for two systems of reasoning. *Psychol Bull* 1996;**119**:3–22.
Soon CS, Brass M, Heinze H, *et al*. Unconscious determinants of free decisions in the human brain. *Nat Neurosci* 2008;**11**:543–5.
Soon CS, He AH, Bode S, *et al*. Predicting free choices for abstract intentions. *Proc Natl Acad Sci* 2013;**110**:6217–22.
Stanovich, K.E., West, R.F. Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences* 2000;645-726.
Stetson C, Cui X, Montague PR, *et al*. Motor-sensory recalibration leads to an illusory reversal of action and sensation. *Neuron* 2005;**51**:651–9.
Wason PC, Evans J. St.B.T. Dual processes in reasoning? *Cognition* 1975;**3**:141–54.
Wegner DM. Precis of "The Illusion of Conscious Will". *Behav Brain Sci* 2004;**27**:649–92.
Wegner DM, Wheatley T. Apparent mental causation. Sources of the experience of will. *Am Psychologist* 1999;**54**:480–92.
Wenke D, Haggard P. How voluntary actions modulate time perception. *Exp Brain Res* 2009;**196**:311–8.

Appendix 1

1. A circle is more pleasing than a square
2. It's okay to expose kids to pornography
3. Plastic bags should be banned
4. Food is more important than water
5. Cats are better than dogs
6. It's better to study three hours straight than to break it up into smaller intervals
7. Apples are better than bananas
8. Kids are not capable of doing great things
9. Real books are easier to read than e-books
10. I'd rather be a vampire than a zombie
11. Women are not valued as high as men in work environment
12. We determine our own happiness
13. I would give money to a panhandler
14. I prefer Summer than Winter
15. It's okay to tell white lies
16. Death penalty should be enforced in every country
17. I'd rather kill a cockroach than a mosquito
18. I choose my family's happiness over my own
19. Tea is better than coffee
20. Leonardo DaVinci is a great artist

Appendix 2

1. It's okay to cheat on an exam
2. Lying is okay if it keeps me safe
3. If I saw someone being attacked, I would help
4. I would give up a friend for money
5. I am happy for the success of my friends
6. I sympathize with wealthy people who have no real friends
7. I like red more than blue
8. I would do anything for a million dollars
9. Freedom is more important than death
10. Money can't buy happiness
11. To save a village, it's okay to sacrifice a child
12. It's okay to publicly criticize celebrities
13. Children should not have cell phones
14. When a child does something wrong, she should not be punished
15. I am responsible for my actions even when I'm intoxicated
16. It is my responsibility to help conserve water
17. If I found money, I would keep the cash
18. You should not curse in front of kids
19. It's okay to speed when you are running late to class
20. A cold blooded killer should receive the death penalty