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# Sleep deprivation produces feelings of vicarious agency

Nicholas Hon [a,*], Jia-Hou Poh [b]

[a] Department of Psychology, National University of Singapore, 9 Arts Link, Singapore 117570, Singapore
[b] Centre for Cognitive Neuroscience, Duke-NUS Graduate Medical School, 8 College Road, Singapore 169857, Singapore

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ABSTRACT

A variety of self-related psychological constructs are supported by the fundamental ability to accurately sense either self-agency or lack of agency in some action or outcome. Agency judgments are typically studied in individuals who are well-rested and mentally-fresh; however, in our increasingly fast-paced world, such judgments often need to be made while in less optimal states. Here, we studied the effect of being in one such non-optimal state – when sleep-deprived – on judgments of agency. We found that 24 h of total sleep deprivation elevated agency ratings on trials designed to produce a strong sense of *non-agency*. These data provide the first evidence that physiological state variables can affect agency processing in the normal population.



## 1. Introduction

We are able to distinguish between actions and outcomes that we author and those we do not. The first of these, the ability to monitor our own agency in some action or outcome, is central to our self-evaluations and supports our self-regulatory behaviours (Carver & Scheier, 1998). The second, the ability to monitor our lack of agency (or "*non-agency*") in an action or outcome, is equally essential because it aids in maintaining the integrity of our self-concepts, ensuring we are able to appropriately distinguish ourselves from others and from the workings of the world around us. Beyond personal relevance, these abilities underpin our social and legal systems, wherein the ability to recognize personal responsibility or lack of responsibility plays an important role in the attribution of blame or the giving of credit (Bandura, 2001; Haggard & Tsakiris, 2009).

A prevailing idea is that a sense of self-agency is produced when the predicted outcome of a specific action matches the actual outcome that occurs (Frith, Blakemore, & Wolpert, 2000; Moore & Haggard, 2008; Wegner & Wheatley, 1999). For example, we feel a strong sense of agency if we push an object and it moves away from us in a direction and speed consistent with the applied force. On the other hand, a mismatch between the predicted and actual outcome is generally an indicator of one's non-agency. We might, for example, feel a lack of agency if we pushed an object and it came towards us. Supporting the notion that sensing either self-agency or non-agency is determined by a comparison process like the one described above, a number of studies have demonstrated what have come to be known as "agency distortions" by manipulating the relationship between predicted and actual outcomes. For example, agency ratings can be diminished via manipulations that produce (real or perceived) discrepancies between these (Sato, 2009; Sato & Yasuda, 2005; Wenke, Fleming, & Haggard, 2010). Conversely, when a situation is crafted such that actual outcomes strongly match prior thoughts, agency ratings are elevated even when the individual has no real control over said outcomes; that is, a kind of "vicarious agency" is experienced (Wegner, Sparrow, & Winerman, 2004; Wegner & Wheatley, 1999).

* Corresponding author.
*E-mail address:* psyhonn@nus.edu.sg (N. Hon).

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Now, agency processing is typically studied with participants who are in a state of rested wakefulness; that is, when generally well-rested and mentally "fresh". However, in our increasingly fast-paced and time-demanding world, agency judgments will often need to be made when one is in a less optimal psycho-physiological state, and it is unclear whether simply being in a non-optimal state can affect the accuracy of agency judgments. In fact, it is still unknown whether state variables in general have any effect on agency processing. In the study reported here, we were particularly interested in the effects of a common non-optimal state – when one is sleep deprived – on agency processing. Sleep deprivation is known to negatively affect a number of cognitive operations including attention, memory and decision making (Harrison & Horne, 2000; Lim & Dinges, 2010). Of greatest relevance here, there is also evidence that processing of mismatches between expectations and actualities in general is compromised by sleep deprivation (Morris, So, Lee, Lash, & Becker, 1992; Raz, Deouell, & Bentin, 2001). As mentioned earlier, a sense of non-agency is experienced when there is a mismatch between the predicted and actual outcome. Hence, we made the minimal prediction that sensing non-agency, in particular, would be susceptible to the effects of sleep deprivation.

In this study, participants encountered trials designed to produce either a strong sense of agency or a strong sense of non-agency. We assessed explicit agency judgments on these trials when participants were in a state of rested wakefulness and when sleep deprived.

## 2. Materials and methods

### 2.1. Participants

Thirty-six participants (15 females and 21 males, range: 18–26 years old) contributed to this study. All participants had regular sleep habits, were not on any long term medications, had no symptoms or history of sleep disorders, had no history of psychiatric or neurological disorders and drank less than 3 caffeinated drinks per day.

Sleeping patterns for each participant were monitored, via wrist-worn actigraphs, throughout the entire duration of the study, and all participants had a regular schedule of 6.5–9 h of sleep (sleeping no later than 1230 h and waking no later than 0900 h). Furthermore, all participants indicated that they had not taken any medication, alcohol or caffeine within 24 h of the test sessions.

### 2.2. Rested Wakefulness (RW) and Total Sleep Deprivation (TSD)

Participants made three visits to the laboratory, attending an initial briefing session, followed by the RW and TSD sessions. RW–TSD session order was counter-balanced across participants. Each session was separated by at least one week to ensure that, for those who underwent the TSD session first, the effects of sleep deprivation would have time to dissipate before the subsequent testing session.

For the TSD session, participants arrived at 2100 h on the evening prior to the day of the experiment. Participants were kept awake and monitored in the laboratory, with hourly assessments of subjective sleepiness and psychomotor vigilance being performed until 0600 h, after which the experimental session proper began. Participants took part in the RW session at 0800 h after a normal night of sleep. These represent the point at which the deleterious effects of a single night's sleep loss on behaviour is at its greatest (Doran, Van Dongen, & Dinges, 2001; Graw, Krauchi, Knoblauch, Wirz-Justice, & Cajohen, 2004) and the typical start of a school/work day respectively. Hence, the TSD effects described here reflect the interaction of circadian and homeostatic contributions (e.g., Liu, Verhulst, Massar, & Chee, 2015; Venkatraman, Huettel, Chuah, Payne, & Chee, 2011).

This procedure was approved by an Institutional Review Board, and all participants provided informed written consent prior to participation.

### 2.3. Agency judgment task

Participants performed a single block of a judgment of agency task (Fig. 1). In this task, they made self-initiated and self-decided up- or down-arrow key presses in response to the appearance of a white dot in the centre of a black screen. Following the key press, the dot moved in a direction that was either spatially congruent with the key press (e.g. dot moved down after a down-arrow key press) or not (e.g. dot moved down after an up-arrow key press). We term the former *agency trials* because spatial congruence between actions and outcomes in this type of paradigm typically produces a strong sense of agency, and the latter *non-agency trials* as spatial incongruence typically produces a strong sense of non-agency (Hon, Poh, & Soon, 2013; Shanks & Dickinson, 1991). The dot's movement lagged the key press with a delay of 100, 400 or 700 ms, with all delay periods being equally represented in agency and non-agency trials. Preliminary analysis revealed that delay did not interact with the critical state manipulation ($F < 1$, n.s.); therefore, for the main analysis, the data were collapsed over delay periods.

Agency and non-agency trials each accounted for 50% of the total number of trials. For each trial, after the dot had completed its movement, participants were asked to indicate how much they felt the dot's movement was caused by their

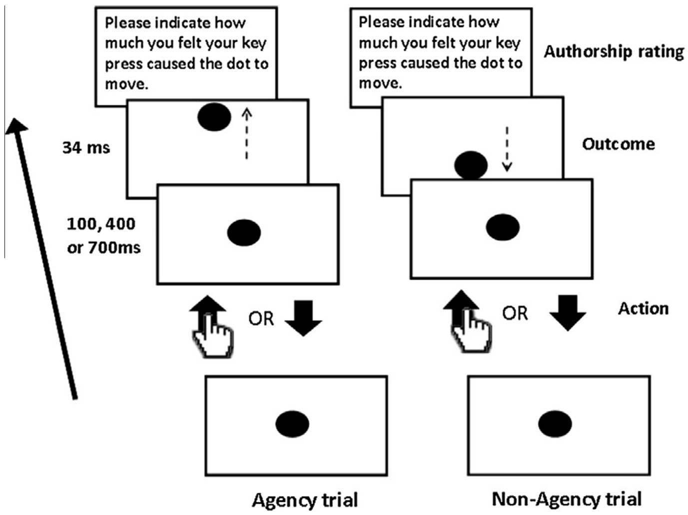


**Fig. 1.** Illustration of the paradigm.

action (i.e. their key press). Ratings were made using a 7-point (1 = 'Not at all'; 4 = 'Not sure'; 7 = 'Definitely me') scale. The agency task as a whole comprised a total of 126 trials, with trial order randomized for each subject.

The experiment was performed on a Mac desktop running the Psychophysics Toolbox, with the stimuli presented on a 21″ LCD display.

## 3. Results

An examination of the Karolinska Sleepiness Scale scores provided by participants at the start of the RW and TSD sessions confirmed that they felt subjectively sleepier after total sleep deprivation ($M = 7.22$, SD = 1.45) than after a regular night's rest ($M = 2.94$, SD = 1.93), $t(35) = 14.025$, $p < .001$.

With the agency ratings, to ensure that source monitoring difficulties would not play a significant role in our results, we removed "inversion errors" (i.e. high end ratings on non-agency trials or low end ratings on agency trials) from our data prior to analysis (Hon et al., 2013).[1]

To begin with, we compared the TSD effect (difference between ratings made in TSD and RW states) in our agency and non-agency trials. To do this, we expressed TSD effects in agency and non-agency trials as a percentage of their respective RW baselines. That is, for each subject, we computed the following for both agency and non-agency trials: $[(\text{Ratings}_{TSD} - \text{Ratings}_{RW})/\text{Ratings}_{RW}] \times 100\%$. This is depicted in Fig. 2a. Comparing them, we found that the effect of TSD was significantly greater for non-agency trials than agency trials, $F(1,35) = 5.758$, $p = .022$. Subsequent one-sample $t$-tests revealed that the ~26% TSD-related increase in ratings observed in the non-agency trials was significantly greater than zero [$t(35) = 2.77$, $p = .009$], but that TSD had no effect on agency trials ($t < 1$, n.s.). An examination of the raw ratings in the two trial types revealed an identical picture. For the agency trials, there was no difference between ratings produced in TSD and RW states ($F < 1$, n.s.; Fig. 2b). For the non-agency trials, on the other hand, we found that TSD reliably elevated ratings relative to RW, $F(1,35) = 6.362$, $p = .016$ (Fig. 2c). That is, subjects experienced vicarious agency[2] on trials in which they did not control the direction of the dot's movement.

TSD is known to adversely impact the ability to maintain attention across the span of an experiment, typically manifest as a reduction in performance as a function of time-on-task. To assess whether our results were a consequence of such, we re-cast our non-agency trial data to include experiment half (1st vs 2nd) as a variable (Fig. 3a). We entered these data into a fully-within 2 (state: TSD, RW) × 2 (half – 1st, 2nd) ANOVA. We found main effects of state [$F(1,34) = 6.254$, $p = .017$] and half [$F(1,34) = 19.283$, $p < .001$], but no interaction between them ($F < 1$, n.s.).[3] This indicates that the magnitude of the TSD effect on ratings in the non-agency trials was constant across the experiment and, therefore, that an impaired ability to sustain

[1] Inversion errors were defined as >4 ratings on non-agency trials and <4 ratings on agency trials. Critically, there was no difference in the number of "inversion errors" made in RW and TSD (11.9% vs 13.1%; $t < 1$, n.s.), supporting the idea that these errors were unrelated to the central state manipulation. Including these errors did not change the pattern of results obtained in the main analysis.

[2] "Vicarious agency" is typically used to refer to an elevation of ratings in non-agency situations, although such elevated ratings do not necessarily cross over into the agency end of the scale (Pronin, Wegner, McCarthy, & Rodriguez, 2006; Wegner et al., 2004).

[3] The $dfs$ for this analysis are different from the main analysis because we removed one participant who had no valid scores from one half of the experiment (i.e. all scores from that half were inversion errors). Removing this participant from the main analysis did not change the pattern of results.

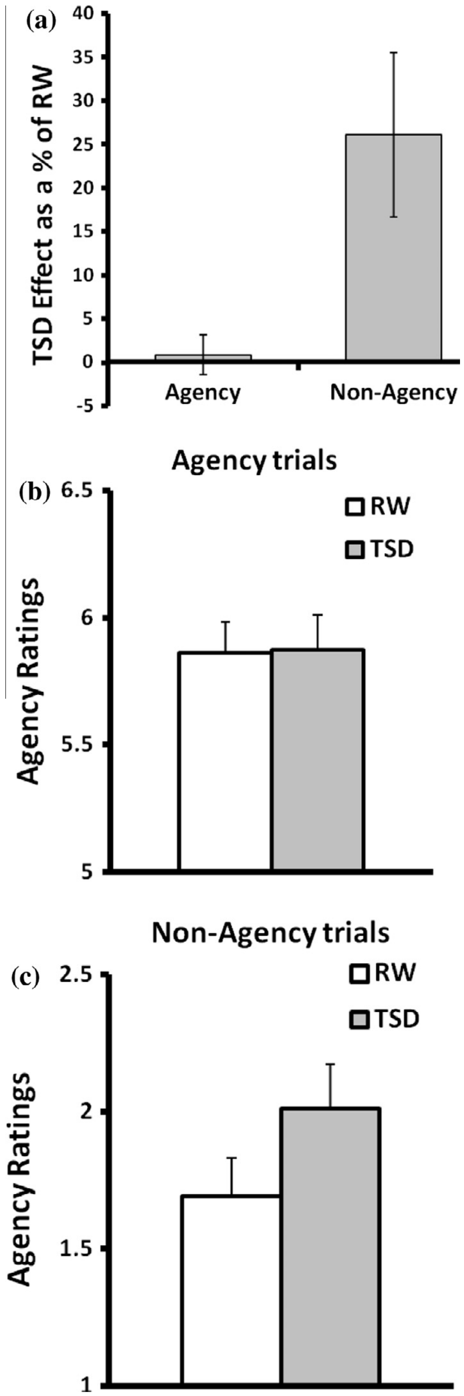


**Fig. 2.** (a) Mean TSD effects (i.e. $\text{Ratings}_{\text{TSD}} - \text{Ratings}_{\text{RW}}$) in agency and non-agency trials presented as a percentage of their respective RW baselines (see Main Text). (b) Mean ratings for agency trials while in TSD and RW states. (c) Mean ratings for non-agency trials while in TSD and RW states. The increase in ratings in non-agency trials indicates that participants become less certain regarding their lack of agency in those trials as a consequence of sleep deprivation. Error bars indicate 1 SEM.

attention was not a factor in the production of our key result. Buttressing this, we also found a positive relationship between the magnitude of the 1st- and 2nd-half TSD effects ($r = .72$, $p < .001$; Fig. 3b), indicating that vulnerability to TSD at the individual subject-level was maintained across both halves of the experiment.

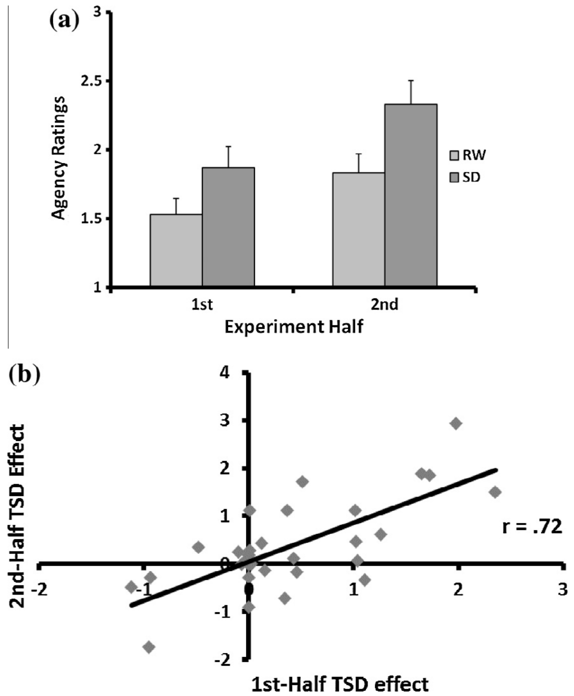


**Fig. 3.** (a) Mean ratings in non-agency trials as a function of experiment half (1st, 2nd). Error bars indicate 1 SEM. (b) Correlation between 1st- and 2nd-half TSD effects (i.e. $\text{Ratings}_{TSD} - \text{Ratings}_{RW}$) in non-agency trials.

## 4. Discussion

Earlier studies ably demonstrated that agency processing can be affected by trial-specific manipulations; for example, as when presenting, on different trials, information that promotes either stronger or weaker matches between predicted and actual outcomes (Linser & Goschke, 2007; Sato & Yasuda, 2005; Wenke et al., 2010). Here, we demonstrate that agency processing can also be influenced by the physiological state one is in. Our main finding was that being in a sleep-deprived state had a reliable effect on an individual's ability to accurately sense a lack of agency in a given outcome. That is, we observed that sleep deprivation produced vicarious agency in non-agency trials. Ratings on agency trials, however, were unaffected by TSD.

The comparison process underpinning agency judgments has three key elements: the generation of a predictive mental representation of the outcome, the apprehension of the actual outcome and the comparison between the two. Given that TSD did not affect agency trials, it is unlikely that our results were due to a difficulty in creating predictive representations. This process would have been identical in both trial types, with the two differentiating only after the occurrence of the actual outcome (i.e., when matches or mismatches can be computed). Similarly, since agency trials were left unaffected, it is also unlikely that TSD affected the ability to perceive the actual outcome.[4]

Why, then, did TSD elevate agency ratings in non-agency trials? We propose that TSD affects the comparison process; specifically, by acting to reduce the "quality" of the mismatches between predicted and actual outcomes, making these seem less definitive and thereby producing a sense of vicarious agency. This idea is consistent with two lines of evidence. First, TSD is known to affect the processing of mismatches in general. For example, TSD reduces the magnitude of electrophysiological measures indexing mismatch and error monitoring, the MMN and ERN ERP deflections respectively (Raz et al., 2001; Tsai, Young, Hsieh, & Lee, 2005). Furthermore, TSD is also known to reduce the amplitude of the P300, an ERP deflection associated with expectancy breaches and novelty processing (Gosselin, De Koninck, & Campbell, 2005; Jones & Harrison, 2001; Morris et al., 1992). By their very nature, expectancy breaches and novelty processing involve mismatches between what is expected and what actually occurs. Our data suggest that mismatch processing within the specific context of explicit agency judgments is also affected by TSD.

Second, neuroimaging studies have revealed that sensing non-agency is associated with a network of frontal and parietal areas including the dorsolateral prefrontal cortex, angular gyrus and temporoparietal junction (Chambon, Wenke, Fleming, Prinz, & Haggard, 2013; Nahab et al., 2011). Greater activity is observed in these areas with an increasing sense of

[4] The fact that only non-agency trials were affected also suggests that simple psychomotor mistakes (e.g., pressing the "up" key when the intention was to press the "down" one) did not produce these results. Since trial type could only be determined after the actual outcome occurred, such mistakes should have affected both agency and non-agency trials.

non-agency (Farrer et al., 2003; Nahab et al., 2011). Of particular relevance here, the functioning of these frontoparietal areas (and the mental operations they support) is known to be compromised by TSD (Chee & Chuah, 2008; Harrison, Horne, & Rothwell, 2000; Mu et al., 2005). Accordingly, the accurate sensing of non-agency, being reliant on these areas, is likely to be compromised by any general deleterious effect of TSD on their functioning. It is worth noting that the P300 discussed above appears to leverage on a similar set of frontoparietal regions (Bledowski et al., 2004), suggesting a possible link between general mismatch detection processes and the more specific agency-related ones we are interested in here.

Why were agency trials unaffected here? One possibility, of course, is that sleep deprivation simply does not affect self-agency processing. Another speculative possibility is that self-agency processing is more resistant than its non-agency counterpart to the deleterious effects of sleep deprivation. There is some evidence that self-agency attributions can persist when there are slight deviations between what is predicted and the outcome that actually occurs (Daprati et al., 1997; Dewey, Seiffert, & Carr, 2010; Farrer, Bouchereau, Jeannerod, & Franck, 2008). (Of course, more extreme deviations like outright spatial incongruence between predicted and actual outcomes will lead to the sensing of non-agency.) In light of this latter possibility, future studies might consider examining whether more pronounced levels of sleep deprivation (e.g., 36 or 48 h) might produce an effect even in agency trials.

We are able to rule out several alternative interpretations of our findings. The exclusion of "inversion errors" suggests that our findings are unlikely to stem from source monitoring (or memory) problems. Furthermore, they are not due to vigilance decrements: We found no difference in the magnitude of the TSD effects in the earlier and later halves of the experiment. Similarly, the fact that only non-agency trials were affected by TSD despite both trial types being randomly intermingled suggests that our results were not due to a tonic deficit that affected general task performance in TSD but not RW. Research has suggested that different types of mental tasks may be differentially affected by TSD. More challenging tasks appear to suffer less from the effects of TSD than simpler ones, perhaps reflecting an increased level of participant interest or effort prompted by such tasks (Harrison & Horne, 1998). Could our non-agency trials have been less challenging than our agency ones and, therefore, more vulnerable to the effects of TSD? To assess this, we compared the RW response times of agency and non-agency trials. We found these to be not significantly different from each other ($t < 1$, n.s.), suggesting that participants found both trial types equally challenging to perform.

Total sleep deprivation has well-known effects on general cognitive functions. Less well-described are its effects on processes that are personally-relevant like those pertaining to the self. Here, we demonstrate that TSD can compromise one of the key abilities – the ability to sense one's lack of agency – supporting the integrity of the sense of self. This ability ensures that we do not erroneously assume credit or blame for outcomes/actions we did not author, thereby enabling our self-concepts to be based largely on accurate evaluations of our own actions. The increasing commonness of sleep deprivation in everyday life plausibly introduces an elevated risk of information derived from agency distortions being routinely factored into our self-related psychological constructs.

Furthermore, given that sleep deprivation is commonly experienced, it may be worthwhile considering whether its effect on the sensing of non-agency has practical implications. For example, one might examine whether driving when sleep deprived results in a false sense of control when a vehicle's movement is influenced by external or environmental forces (e.g., when driving on slippery roads). Additionally, it has been known for some time that sleep deprivation increases the likelihood that individuals will accept responsibility for acts they did not author, even when these have adverse consequences on their well-being (Blagrove, 1996; West, Janszen, Lester, & Cornelisoon, 1962). Could the deleterious effect of sleep deprivation on the ability to accurately sense lack of responsibility in outcomes be a possible contributor to this? Needless to say, questions like these would benefit from direct inquiry in the future. Such studies on the practical implications of the agentic effect of sleep deprivation are likely to require the use of more ecologically-tuned dependent measures, possibly in combination with those typically utilized in laboratory settings (e.g., self-report scales).

In conclusion, although agency distortions are typically observed with trial-specific manipulations that target specific component processes (e.g., Linser & Goschke, 2007; Pronin et al., 2006; Sato & Yasuda, 2005; Wegner et al., 2004), here, we demonstrate a distortion that is a consequence of simply being in a non-optimal state. This represents the first evidence that physiological state variables can influence agency processing. Our state manipulation affected a specific process – the processing of mismatches between predicted and actual outcomes – while leaving others untouched. This suggests that state manipulations, like their trial-specific counterparts, are likely to be targeted in their influence.

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