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BRIEF REPORT

Having a sense of agency can improve memory

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Abstract
In most situations, we are able to tell those outcomes we cause from those we do not. By now, research has provided us with a reasonably good understanding of the cognitive processes that underlie this sense of agency – it is thought to be produced by a comparison between a prediction of the outcome and the actual outcome that occurs. What is less clear is whether having a sense of agency can, itself, influence cognition. In the current study, we examined the possibility that sense of agency can affect memory, and we report evidence that stimuli that one feels a sense of agency over are, in fact, better remembered than counterparts without this. This *self-agency effect* can be distinguished from previously described control-related memory enhancements and adds to what we know of the cognitive consequences of having a sense of agency.

Keywords Sense of agency · Self-agency · Cognition · Memory

Introduction

A sense of agency (SoA) allows us to differentiate outcomes that are caused by us from those that are not. The sense of agency supports the "sense of self" and other self-related psychological constructs and processes (Bandura, 2001; Knoblich & Flach, 2003). It does this, in part, by enabling us to distinguish our behaviour (and its consequences) from that of other people and from outcomes caused by natural occurrences of the (physical) world we inhabit. Additionally, the sense of agency has taken on increased relevance in the current digital age because of our extensive interactions with machines and the need to feel in control of these, with a sense of agency being an important consideration when, for example, designing user interfaces.

A primary line of inquiry has been into the cognitive processes that produce SoA, with this effort being a largely successful one. The sense of agency is thought to be produced by a comparison between a predictive mental representation of an outcome (of some given action) and the actual outcome that occurs, with a solid match producing a strong SoA (Frith, Blakemore, & Wolpert, 2000; Sato & Yasuda, 2005; Wegner & Wheatley, 1999). For example, if one pushes a ball and the ball rolls forward in the direction of the force applied, a strong sense of agency would be experienced. However, if the ball rolls backwards instead, a sense of non-agency will ensue. Consistent with this proposal, numerous studies have now shown that manipulations that affect matching between predictions and outcomes can influence SoA: Manipulations that minimize this match result in lower SoA (Farrer, Bouchereau, Jeannerod, & Franck, 2008; Metcalfe, Eich, & Castel, 2010; Metcalfe & Greene, 2007), while manipulations that enhance matching elevate SoA (Wegner, Sparrow, & Winerman, 2004; Wegner & Wheatley, 1999). Other work has sought to reveal the cognitive (Hon, Poh, & Soon, 2013, Wen, Yamashita, & Asama, 2016), social (Dewey, Pacherie, & Knoblich, 2014) and physiological factors (Hon & Poh, 2016; van der Westhuizen, Moore, Solms, & van Honk, 2017) that can influence the sense of agency.

What is less well described at the current time, though, is the effect that having a sense of agency has on cognition. By definition, an outcome that one has an SoA over is different to a counterpart that does not have this and, presumably, the two are treated differently psychologically/cognitively. But, how? Here, we examined the possibility that having a sense of agency will have an effect on memory. Although this study is exploratory, we predicted that a sense of agency would enhance memory. There are several possible reasons why one might expect this. For example, the literature indicates that information that is self-relevant enjoys a memory advantage over information that is not

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(Kim & Johnson, 2012). A sense of agency would indicate that a particular outcome is self-caused and, therefore, "belongs" to oneself. Consequently, we might expect that, as with other self-relevant information, information that has an associated SoA will enjoy a memory advantage over counterparts that do not. Alternatively, memory may be enhanced because an associated SoA, which essentially offers additional information, may add a potential cue for retrieval for stimuli that have this. Accordingly, in this study, we assessed the effect of having a sense of agency on memory.

Experiment 1

In this experiment, participants made self-decided and self-initiated up- or down-arrow button presses in response to the presentation of a word stimulus (Fig. 1). After a delay of either 100 or 900 ms, the word either moved in a direction consistent with that indicated by the button press or not. When it stopped moving, participants made agency ratings over the word's movement. In line with the comparison process discussed earlier, previous research using paradigms like this has shown that when there is spatial congruence between action and outcome, a strong SoA is produced (Ebert & Wegner, 2010; Hon, Poh, & Soon, 2013). Thus, in this experiment, we expected higher agency ratings when the word moved in a direction that was consistent with the button pressed and low agency ratings when it moved in an inconsistent direction. As mentioned above, there were two possible delay intervals between action and outcome – a longer one and a shorter one. We employed two action-outcome delays (100 and 900 ms) here because temporal contiguity between action and outcome is known to be able to modulate SoA, with a strong SoA typically experienced when there is only a short delay between action and outcome and a weak SoA when this is long (Guski & Troje, 2003; Michotte, 1963; Young & Sutherland, 2009). Of greatest relevance to the current study, this allowed us to probe the memory consequences of having a strong versus a weak SoA. After the agency task was completed, participants were given a surprise recognition memory test involving the words used in the agency task.

Methods

Materials

The word list used in this experiment comprised 120 words generated from the MRC Psycholinguistics Database (Coltheart, 1981). Eighty of these were used in the agency task, while the remaining 40 words were used as novel foils for the surprise recognition memory test. For the 80 words used in the agency task, these were sorted into four lists, which were then randomly assigned to the various conditions of the experiment (see *Procedure*). Ten words from each condition in the agency experiment were drawn for use in the surprise recognition memory test. These were intermingled with 40 novels foils for a total of 80 trials in the memory test. The words drawn from the different conditions for the memory test were matched on concreteness, frequency and number of letters.

Procedure

The study began with 60 undergraduates from the National University of Singapore performing an 80 trial-block of an agency judgment task (Fig. 1). Each trial began with a fixation sign in the centre of the screen. After 500 ms, a word replaced the fixation sign and participants made self-initiated and self-decided up- or down-arrow key presses in response to the presentation of the word. After a key was pressed, the word remained stationary for either 100 ms or 900 ms before moving. Each delay period accounted for half the total number of trials. When the word moved, it either did so in a direction consistent with that indicated by the key press (e.g., it moved upwards when the up-arrow key was pressed) or not (e.g., it moved downwards when the up-arrow key was pressed). These are termed *Congruent* and *Incongruent* trials, respectively. Thus, crossing the delay (100 ms, 900 ms) and spatial congruence (congruent, incongruent) variables, there were four conditions in the experiment: 100 ms congruent, 100 ms incongruent, 900 ms congruent and 900 ms incongruent. The total number of trials was evenly distributed across these four conditions.

On all trials, the word moved ~ 5.14^{o} of visual angle (when viewed from approximately 60 cm) upwards or downwards

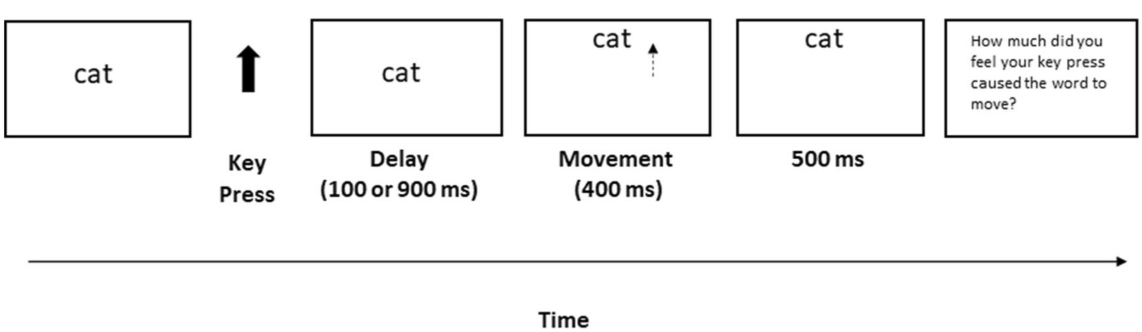

Fig. 1 Illustration of a congruent trial in which a participant pressed the up-arrow button

from its original position, with the exact direction being dependent on the type of trial it was. The movement lasted 400 ms. After reaching its final position, the word remained on the screen for an additional 500 ms before being extinguished. Once the word disappeared, participants were prompted to make an agency rating, indicating how much they felt their action (key press) controlled the word's movement using a 7-point Likert-type scale (1 = "No control", 4 = "Not sure", 7 = "Full control").

Immediately after completing the agency task, participants were given a surprise recognition memory test. Ten words were drawn from each condition (for a total of 40 "old" words) and intermingled with 40 novel foils for this memory test. On each trial, a fixation sign appeared in the centre of the screen for 500 ms, followed by a word. Participants indicated whether they thought the word was novel (by pressing the "Z" key) or previously seen ("M" key).

Results

To begin with, we analysed the agency ratings to assess whether our paradigm successfully produced different levels of SoA. We performed a fully-within 2 (spatial congruence) x 2 (temporal delay) ANOVA on the agency ratings (Fig. 2A). We found main effects of spatial congruence [$F(1,59) = 418.20$, $p < .001$, $\eta_p^2 = .88$] and delay [$F(1,59) = 38.50$, $p < .001$, $\eta_p^2 = .40$], along with a significant interaction between the two [$F(1,59) = 35.56$, $p < .001$, $\eta_p^2 = .38$]. This is the standard finding when these two variables, spatial congruence and temporal contiguity, are manipulated in a paradigm like this (Ebert & Wegner, 2010; Hon, Poh, & Soon, 2013). To confirm that our paradigm was able to produce different levels of SoA, we performed a post hoc t-test on the data from the 100-ms congruent and 900-ms congruent conditions. This revealed that the 100-ms congruent condition produced higher agency ratings than the 900-ms congruent condition [$t(59) = 6.93$, $p < .001$, $d = .90$], consistent with previous findings that temporal contiguity can modulate the level of SoA.

Having established that our paradigm managed to produce both strong (100 ms) and weak SoAs (900 ms), we turn now to the critical memory data (Fig. 2B). Because we were interested in memory differences between stimuli involved in outcomes that had an associated SoA and those that did not, we performed separate planned comparisons (Bonferroni-corrected) between the congruent and incongruent conditions of the two delay conditions.[1] (Recall that, because words were presented throughout the delay period, the stimulus presentation parameters were similar for congruent and incongruent trials within a delay condition, but quite different across delay conditions.) For the 100-ms delay (strong SoA), we found enhanced memory for words in the congruent condition, relative to the incongruent condition [$t(59) = 3.70$, $p < .001$, $d = 0.48$]. For the 900-ms delay (weak SoA), however, we found that both the congruent and incongruent trials resulted in similar levels of memory performance [$t(59) = .60$, $p = .55$, $d = .08$]. Furthermore, a direct comparison between congruent conditions revealed that memory was better in the 100-ms congruent condition than in the 900-ms congruent one [$t(59) = 2.62$, $p = .011$, $d = 0.34$]. Taken together, this indicates a memory enhancement when one experiences a strong sense of agency, but not when there is only a weak one.

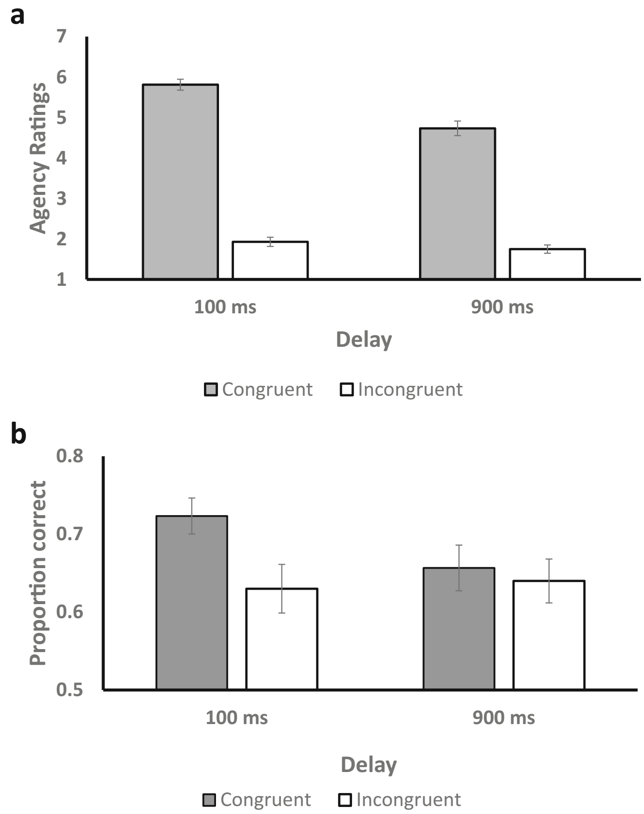

Fig. 2 Agency ratings (**a**) and (**b**) memory data from Experiment 1 presented as a function of trial type and delay. Error bars indicate 1 SEM

Experiment 2

In Experiment 1, because a word would have been presented throughout the delay period, participants spent different amounts of time with the stimuli in the 100- and 900-ms conditions. Could this have caused the results we previously observed? In Experiment 2, we controlled the amount of time that the word stimuli were presented for. Here, on each trial, participants were initially presented with a box stimulus

[1] For completeness, a 2 (spatial congruence) x 2 (temporal delay) fully-within ANOVA on the memory data from Experiment 1 was also performed. This revealed a main effect of congruence [$F(1, 59) = 8.86$, $p < .005$] and the expected interaction between the two variables [$F(1, 59) = 4.03$, $p < .05$]. The main effect of delay did not reach significance [$F(1, 59) = 2.73$, $p > .10$].

instead of a word. As in Experiment 1, participants made up- or down-arrow button presses, after which the box would move in a direction consistent with the button pressed or not. Critically, when it reached its final position, a word was presented inside the box for 500 ms. This limited the amount of time that a participant had with a word to 500 ms in all conditions. Participants made agency ratings over the box's movement, and were later given a surprise memory test on the words that appeared in the box.

Methods

Procedure

Fifty-one participants from the same pool took part in this experiment. The set-up, delay parameters and word stimuli used in this experiment were identical to those in Experiment 1 with the following exception: At the start of each trial of the agency task, participants were presented with a box stimulus. As before, on each trial, they made self-decided and self-initiated up- or down-arrow button presses. Like Experiment 1, after a delay of 100 or 900 ms, the box moved in a manner that was either consistent with the direction indicated by the button pressed (Congruent) or not (Incongruent). When the box reached its final position, a word was presented inside the box for 500 ms before being extinguished. Thus, participants would have only 500 ms of exposure to any given word, regardless of condition. Participants made agency judgements over the box's movement with the same 7-point Likert-type scale used in Experiment 1.

Immediately after the agency experiment ended, participants were given a surprise recognition memory test on the words. As before, the memory test comprised a total of 80 words: Ten words drawn from each condition (for a total of 40 "old" words) that were intermingled with 40 novel foils. The response set-up for the surprise memory test in this experiment was the same as that used in Experiment 1.

Results

A fully-within 2 (spatial congruence) x 2 (temporal delay) ANOVA on the agency ratings was performed (Fig. 3A). We found main effects of spatial congruence [$F(1,50) = 292.1$, $p < .001$, $\eta_p^2 = .85$] and delay [$F(1,50) = 18.80$, $p < .001$, $\eta_p^2 = .27$], along with a significant interaction between the two [$F(1,50) = 29.00$, $p < .001$, $\eta_p^2 = .37$]. To assess whether different levels of SoA were also produced in this experiment, we performed a post hoc t-test on the data from the 100-ms congruent and 900-ms congruent conditions. As before, the 100-ms congruent condition was found to produce higher agency ratings than the 900-ms congruent one [$t(50) = 6.34$, $p < .001$, $d = .89$]. This is the same pattern of results observed in Experiment 1.

As with Experiment 1, for the memory data, Bonferroni-corrected planned comparisons revealed enhanced memory for stimuli in the 100-ms congruent condition, relative to the 100-ms incongruent condition [$t(50) = 2.99$, $p = .004$, $d = 0.42$]. As before, we found no difference between the 900-ms congruent and 900-ms incongruent conditions here [$t(50) = .16$, $p = .88$, $d = .02$]. Also consistent with the findings of Experiment 1, the 100-ms congruent condition produced better memory performance than the 900-ms congruent condition [$t(50) = 3.69$, $p < .001$, $d = 0.52$][2].

Overall, the same pattern of results observed in Experiment 1 was obtained here, even though the amount of experience the participants had with the words was controlled for across conditions.

Discussion

In this study, we considered the possibility that a stimulus that one felt a sense of agency over would be remembered better than a counterpart without such an accompanying SoA. We found that participants did, in fact, remember words that they felt a

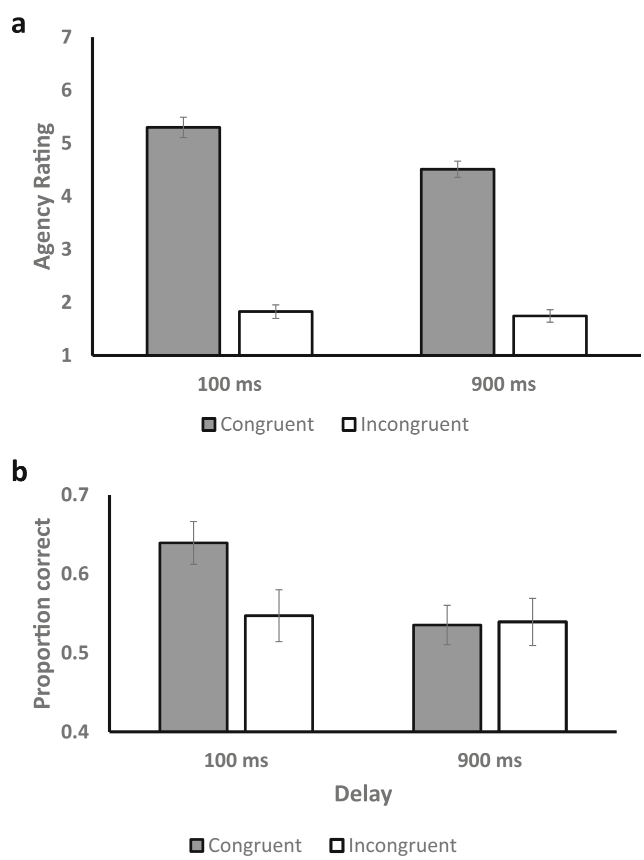

Fig. 3 Agency ratings (**a**) and (**b**) memory data from Experiment 2 presented as a function of trial type and delay. Error bars indicate 1 SEM

sense of agency over better than those without this. However, this advantage was observed only when there was a strong SoA associated with the word (100-ms congruent condition); a weak SoA (900-ms congruent) did not produce it.

Why should SoA affect memory? As the purpose of this study was to offer proof-of-concept that SoA can affect memory, a definitive explanation for why this occurs is still premature. However, we might consider some strong contenders. One possibility is that SoA makes an outcome (and the information this involves) self-relevant. The literature indicates that information tagged as being self-relevant enjoys a memory advantage over information that is not (Kim & Johnson, 2012). For example, in one experiment, participants were presented with items that had a coloured dot super-imposed on them (Kim & Johnson, 2012). The instructions to the participants indicated that, depending on the colour of the dot, the item would belong to the participant or to someone else. Items that were related to the self were remembered better than those that were not. Similarly, a sense of agency indicates to us that a particular outcome is self-caused and, therefore, "owned" by oneself. Self-relevant information may undergo greater elaborative processing than non-self-relevant counterparts because it can be related to a rich network of self-relevant knowledge (Catrambone, Beike, & Niedenthal, 1996; Markus, 1977), possibly making the memory more distinctive and aiding in subsequent retrieval. Another possibility is that an SoA attached to an outcome/stimulus offers extra information that can be used as an additional cue for retrieval, resulting in enhanced memory performance. Having additional retrieval cues has long been known to aid memory (Tulving & Thomson, 1973). It goes without saying that determining exactly how SoA produces enhanced memory is an issue that would benefit from direct inquiry in the future.

One interesting finding here was that only a strong sense of agency produced a memory enhancement. A weak SoA (as in the 900-ms congruent condition) did not. One reason for this might be that participants were not completely certain about self-agency in the 900-ms congruent condition. Supporting this, the mid-point "4" rating (indicating uncertainty about the cause of a stimulus' movement) on the scale we used fell within 1 SD of the mean rating of that condition in both experiments. It is also worth noting that other studies that manipulated action-outcome delays report this same observation: long delays often result in agency ratings that can overlap with the point of the scale that indicates uncertainty regarding agency (Ebert & Wegner, 2010; Wen, Yamashita, & Asama, 2015). Thus, it appears that only strong SoAs, in which one is very certain of self-agency, produce a memory enhancement. Weak or uncertain levels of SoA apparently do not. Future studies may, by adopting more fine-grained parametric designs, for example, assess how strong an SoA must be before a memory enhancement is observed.

It is also important to rule out alternative interpretations. To begin with, the memory enhancement effect reported here is not based on sensorimotor differences between conditions. In all conditions, participants performed actions and were presented with outcomes. The difference between them lay in whether an outcome had an associated sense of agency or not. In the same vein, these findings are different from the enactment effect (Cohen, 1981), in which memory is better for words when participants perform the actions indicated by the words (e.g., performing a punching action when presented with the word "punch") during the encoding phase. Here, the words were never acted out; rather, the word as an object was acted upon.

The *self-agency effect* we report here should also be distinguished from "control-related" memory effects. Choosing a stimulus over others (Murty, DuBrow, & Davachi, 2015), self-generating to-be-remembered stimuli (Jacoby, 1978) and self-directed study (Markant, DuBrow, Davachi, & Gureckis, 2014) have all been known to produce memory enhancements. However, these are quite different from what we report here, in that choosing, self-generation and self-directed study plausibly reflect the impact that exercising control over learning processes can have on memory. Volitionally choosing a stimulus, for example, can influence the attentional emphasis one places on one stimulus over another. Better memory for self-generated stimuli, on the other hand, may reflect a difference in the level of processing such stimuli might enjoy as a consequence of self-production. Similarly, self-directed study may influence the flow of information during learning. Here, however, participants decided on and controlled their actions in the same way in all conditions, with the only difference being the SoA experienced once an outcome occurred. Now, although there is a difference between the *self-agency effect* we report here and the aforementioned control-related ones, it is worth considering the possibility of a relationship between them. Notice that self-directed study, self-production of stimuli and choosing of stimuli all require a participant to be an active agent, which would presumably entail a sense of agency. One possibility, then, is that the *self-agency effect* may be the most basic component of these control-related memory enhancements, reflecting the impact of simply having a sense of agency, with self-involved processes affecting learning flow, attentional emphasis and encoding being scaffolded on this. This possibility is something that could be addressed in future work.

Finally, we might consider two non-memory-based alternatives. First, could these results have been caused by demand characteristics, with participants guessing that memory should be better for stimuli they felt a sense of agency over and behaving accordingly? This is unlikely because memory performance in the 900-ms congruent condition was not significantly different from the 900-ms incongruent one, even though agency ratings were much higher in the former than the latter. This suggests that participants were unlikely to have been trying to couple memory performance to their agency ratings. Second, it has been found that having a sense of agency can affect attentional prioritization of stimuli (Huffman & Brockmole, 2020; Wen & Haggard, 2018). Could our memory results have been produced by different attentional priorities, with stimuli having an associated SoA being attended to more easily than those without this? This possibility, too, seems unlikely. Recall that, in the critical frames of Experiment 1, the only stimuli on the screen was a single word. So, there would have been no need for attention to prioritize one stimulus over others.

To date, there has been precious little work looking into the cognitive effects of SoA. One notable exception is time perception, with a sense of agency known to produce a compression of the perceived temporal interval between action and outcome (Haggard, Clark, & Kalogeras, 2002; Moore & Haggard, 2010). Additionally, SoA appears to play a role in how we parse stimuli in a visual display, with individuals finding it easier to localise stimuli that they feel they are controlling (Huffman & Brockmole, 2020; Wen & Haggard, 2018). Our results thus extend our knowledge of the cognitive impact of SoA, showing that it also has an effect on memory.

In conclusion, the current study offers proof-of-concept that SoA has an impact on memory. The idea at the core of this is that information that has an associated SoA is treated differently (cognitively) from that which does not. Here, we probed one of the cognitive consequences of such different treatment and found that SoA is able to influence memory. There is a clear utility to having better memory for outcomes (and their attendant information) that are known to be self-caused. For example, self-caused outcomes are more useful than other-caused ones for computations of perceived self-efficacy (Bandura, 1982), in that we can accurately assess what we do well only if we can tell which outcomes we have actually caused to happen. Presumably, better memory for self-caused outcomes would enhance the capacity for such information to be used in self-related computations over an extended period of time, beyond the exposure duration of an outcome. (This suggests an interesting line of future inquiry: establishing exactly how long the self-agency memory advantage lasts for. This could be assessed by, for example, systematically manipulating the interval between the agency task and surprise memory test.) More broadly, an understanding of how SoA affects cognition may help us better understand how it is able to support social-psychological processing, as well as offer potential insight into the various clinical disorders that have agency distortions as part of their symptomology (Frith, Blakemore, & Wolpert, 2000; Gentsch, Schütz-Bosbach, Endrass, & Kathmann, 2012).

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Open Practices Statement The data and materials for the experiments reported here are available upon request. Neither of the experiments was preregistered.

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