Exploring the impact of mindfulness on false-memory susceptibility

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Abstract

Wilson et al. (2015) presented data from three well-powered experiments suggesting that a brief mindfulness induction can increase false memory susceptibility. However, we had concerns about some of the methodology, including whether mind-wandering is the best control condition for brief mindfulness inductions. We report here the findings from a pre-registered double-blind randomised controlled trial designed to replicate and extend the findings. 287 participants underwent 15-minute mindfulness or mind-wandering inductions or completed a join-the-dots task, before being presented with lists of words related to non-presented critical lures followed by free recall and recognition tasks. There was no evidence for an effect of state of mind on correct or false recall or recognition. Furthermore, manipulation checks revealed that mindfulness and mind-wandering inductions activated overlapping states of mind. Exploratory analyses provide some support for mindfulness increasing false memory, but it appears that mind-wandering may not be the right control for brief mindfulness research.

Keywords: false memory, mindfulness, mind-wandering, pre-registration, replication

Statement of relevance: Mindfulness is a trend that looks as though it is here to stay. It has been shown to reduce stress, to help with chronic pain and to improve depression. Increasing numbers of people are using mindfulness apps or taking courses in mindfulness. Furthermore, it is starting to be introduced in schools to improve pupils' mental health and well-being. Although much is known about the cognitive benefits of mindfulness, there is still much that we don't know. When we consider the impact of mindfulness on memory and specifically false memory, the research findings are mixed. The research reported here suggests that mindfulness may have no impact on memory, but that there is still work to be done understanding the best way to test this.

Increased false-memory susceptibility following mindfulness meditation: Does it replicate?

Wilson et al. (2015) reported that a brief mindfulness induction increased false memory susceptibility. Media reports soon circulated of "How mindfulness plays havoc with memory" (Telegraph, 2015). Close reading of the research coupled with two subsequent published research articles—one supporting Wilson et al. and one contradicting them—suggest that this conclusion may be premature.

The DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) is an effective method for eliciting false memories in the laboratory. Participants are presented with lists of words (e.g., bed, rest, awake) associated with a non-presented critical lure item (e.g., sleep). On subsequent memory tasks—such as free recall or recognition—participants typically have false memories for the non-presented lure as well as true memories for presented list items.

Wilson et al. (2015) used the DRM paradigm to explore the effect of mindfulness and mind-wandering inductions on false recall. In Experiment 1, they used the relevant mind induction before showing participants words related to the non-presented critical lure word 'trash' and giving them a free recall task. Mindfulness induction led to 39% false recall and mind-wandering induction to 20%. They suggested that mindfulness increases false memory susceptibility. However, the authors did not include a baseline condition of 'no induction'.

In Experiment 2, Wilson et al. (2015) explored whether mindfulness increases false recall rather than mind-wandering reducing it. They presented participants with DRM lists before and after the mind inductions and compared recall performance pre- and post-induction. In the mind-wandering condition, false recall was the same pre- and post-induction, whilst in the mindfulness condition false recall increased post-induction. However, there was again no baseline control condition and so it is difficult to know whether mindfulness and mind-wandering increase or reduce false memories relative to no induction, especially given two other minor methodological concerns: (1) the pre- and post-manipulation lists weren't counterbalanced; and (2) the backwards associative strength (BAS) of the sets was not matched. BAS—defined as "...the average tendency for words in the study list to elicit the critical item on a free association test" (p. 387)—is a key predictor of false recall (Roediger et al., 2001). In Wilson et al.'s Experiment 2, the BAS of the pre-induction lists was higher (range 0.100–0.353, M=0.214) than the post-induction set (range 0.006–0.184, M=0.115); so, absent of any mind induction, one would expect higher levels of false recall in the pre-induction lists.

Using mind-wandering as a control condition for mindfulness would be less problematic if we knew what the effect of mind-wandering on false recall should be. To our knowledge, no previous work has addressed this. Mrazek, Franklin, Phillips, Baird, and Schooler (2013) define mind-wandering as "...a shift of attention from a task to unrelated concerns" (p776). Most theories of false memory posit that some encoding of the list items needs to take place for false memories to be facilitated, for example via spreading activation (activation/monitoring account; e.g. Roediger, Watson, McDermott, & Gallo, 2001) or gist extraction (fuzzy trace theory; Reyna & Brainerd, 1995). According to these theories—and previous findings—the fewer items to be encoded, the fewer false memories created (e.g., Robinson & Roediger, 1997). If mind-wandering is effectively induced such that participants are shifting their attention from the task (encoding the list items) to unrelated concerns, these theories might reasonably predict a drop in false memories rather than an increase. Alternatively, response bias—for example, participants believe they need to provide a certain number of answers but are unable to accurately recall or recognise sufficient—might result in increased false memories.

It is not clear that mind-wandering was successfully induced in Wilson et al.'s (2015) study. If participants had shifted their attention away from the task, why was there no difference in their performance on correct recall of presented items between the mind-wandering and mindfulness conditions in either experiment? Risko, Anderson, Sarwal, Engelhardt and Kingstone (2012) provided evidence that correct memory should be impaired by mind-wandering by observing that as mind-wandering increased during a lecture, memory for the lecture material decreased.

A final methodological observation is that there was no measure of whether the mindfulness and mind-wandering inductions actually induced different mental states in participants. Several scales have been developed to measure either state- or dispositional-mindfulness, and whilst it would be nice to believe that an experimental induction works, it cannot be assumed. Indeed, Brown and Ryan (2003) observed that both dispositional and state mindfulness vary across participants.

Since 2015, two further articles have been published exploring the impact of a brief mindfulness manipulation using the DRM paradigm. Experiment 2 by Rosenstreich (2016) used brief (30 minute) mindfulness/mind-wandering manipulations and found that both correct and false recognitions increased in the mindfulness condition, supporting Wilson et al.'s (2015) findings. However, only 40 participants took part in this between-subjects study, there was no baseline condition, and the effectiveness of the mindfulness manipulation was not measured. Baranski and Was (2017) explored the effects of 15 minute mindfulness/mind-wandering manipulations and warning vs. no warning instructions on false memories. Similar to Wilson et al.'s Experiment 2, in their second Experiment, they had participants (a) study 6 DRM lists each followed by free recall, (b) receive the induction, then (c) study 6 more lists with free recall. They used three inductions: mindfulness, mind-wandering, and puzzle completion. There was no difference in the amount of false recall between the conditions, and in all conditions false recall declined post-manipulation. Exploratory analyses suggested this decline was greatest in the mindfulness condition. These findings thus conflict with Wilson et al.; however, they too did not measure whether mindfulness was induced.

In light of the methodological issues identified in Wilson et al. (2015), we pre-registered a study to replicate and extend Wilson et al.'s Experiment 1. Specifically, we: (a) evaluated participant mindfulness pre- and post-induction; (b) evaluated mind-wandering post-induction; (c) included mindfulness, mind-wandering, and join-the-dot conditions; (d) measured participants' performance on 12 DRM wordlists—counterbalanced for BAS—rather than a single list; and (e) measured both free recall and recognition performance. This was conducted in a double-blind randomised controlled trial (Gilder & Heerey, 2018). Our hypotheses were:

Free recall: Correct recall will be highest in the mindfulness condition and lowest in the mind-wandering condition. False recall will be highest in the mind-wandering condition and lowest in the mindfulness condition[1].

Recognition Task: Correct recognition will be highest in the mindfulness condition and lowest in the mind-wandering condition. False recognition will be highest in the mind-wandering condition and lowest in the mindfulness condition. Filler recognition will be highest in the mind-wandering condition and lowest in the mindfulness condition.

Recognition task - Remember responses**:** For correct recognition: Remember responses will be highest in the mindfulness condition and lowest in the mind-wandering condition. For false recognition: Remember responses will be highest in the no manipulation

[1] In hindsight, we should have hypothesised that false memory should be reduced in both mindfulness AND mind-wandering conditions relative to join-the-dots, but for different underlying reasons: for mindfulness, because better source monitoring should be possible, and in mind-wandering because if the list items are not well encoded, then the spreading activation needed for false memories should not take place.

condition and lowest in the mindfulness condition. Filler recognition: Remember responses will be highest in the no manipulation condition and lowest in the mindfulness condition.

Recognition task - Know responses**:** For correct recognition: Know responses will be highest in the mindfulness condition and lowest in the mind-wandering condition. For false recognition: Know responses will be highest in the mind-wandering condition and lowest in the mindfulness condition. Filler recognition: Know responses will be highest in the mind-wandering condition and lowest in the mindfulness condition.

Method

Participants

Our target sample size was informed by Wilson et al. (2015). The effect size in their study 1 was "medium" with a Cohen's d = 0.5. The equivalent effect size in ANOVA is Cohen's f = 0.25. To power our experiment at 95% with the same effect size (0.25) as Wilson et al. we required at least 250 participants. This differs from the power analysis calculation in our pre-registration, where we incorrectly stated the power analysis suggested a total sample size of 280. Hence, our final sample size provided more power than planned.

A total of 302 participants were recruited through Keele University's School of Psychology research participation scheme, through social media, and through paper advertisements on Keele University campus. Participants either received course credit or were paid £7 for participating. Participants were at least 18 years of age (M=23.44, SD=9.80) and had English as their first language.

Following our pre-registered exclusion plan, fifteen participants had to have their data removed as follows: 6 were non-native English speakers (violating one of our eligibility criteria); 2 overran the one hour time slot that the participants were booked in for, and so their participation had to be terminated early; 4 participants did not complete the experiment; 1 did not complete any of the free recall data; and 2 further participants only completed free recall after some of the lists, thus violating the stopping rule that required 'complete' sets of data. This left us with 287 participants. A sensitivity analysis (see supplementary material) showed our final sample size gave us 80% power to detect an effect size as small as f = 0.185, which is 25% smaller than the effect size reported by Wilson et al. (2015).

Materials and Procedure

The study received ethical approval from the Keele Ethical Review Panel on 10th May 2017, document number: ERP1331.

Participants were tested individually in a lab with an experimenter present to ensure full participation (i.e., that the subject was not using their mobile phone etc.). The experimenter was blind to the experimental condition of the participant as the random assignment to condition was done using the Qualtrics software. After providing informed consent, participants completed the State Mindfulness Scale (SMS; Tanay & Bernstein, 2013) which consists of two subscales, a 15 item state mindfulness of mind scale and a 6 item state mindfulness of body scale. The 21 items were presented in a random order. Participants then completed the relevant mindfulness/mind-wandering or control condition activity.

Wilson et al. (2015) used 15 minute mindfulness and mind-wandering inductions recorded by Marilee Bresciani Ludvik at the Rushing to Yoga Foundation. On requesting these recordings from Wilson, he informed us that since the PI Edmund Fantino had recently passed away the precise recordings were not available (Wilson, 2016, personal communication). He provided similar recordings by the same person which we used instead, with participants listening to them via headphones. In the control condition, participants were asked to complete paper-based join the dot puzzles for 15 minutes (this task was identified by

Friese, Messner, & Schaffner, 2012, as being "neither boring nor resource demanding" p. 1019).

Participants then completed the State Mindfulness Scale items in a different random order, and the Retrospective Mind-wandering scale (the Thinking Content component of the Dundee Stress State Questionnaire; Matthews et al., 1999) which consists of an 8 item task-related interference scale (TRI) and an 8 item task-unrelated thought scale (TUT).

18 lists of 15 words were selected from Roediger et al. (2001). Each participant saw 12 of the 18 lists and the lists were counterbalanced by dividing them into 3 sets. The lists were chosen and counterbalanced based on the two factors that predict false recall—backwards associative strength and veridical recall—and also on the norms for false recall and false recognition for each list. The 15 words per list were presented individually in the Qualtrics default black font, size 36 for 1.5s in the middle of the screen. After each list was presented, participants were given 3 minutes to type as many words as they could remember from the list. Once this was repeated for all 12 lists, participants completed a Remember/Know/Guess recognition task. The recognition test consisted of 72 items: 36 presented items (3 from each list), 12 critical lure items (1 from each list) and 24 filler items (3 list and 1 lure items from the 6 non-presented lists which were counterbalanced across subjects). For each item, participants had to identify whether it was old or new and then for those items identified as old, they had to select between a Remember, Know or Guess responses. The definitions (adapted from Dewhurst & Anderson, 1999) were provided in the instructions and again every time they had to make a selection.

Results

The analytical approach we used was to present standard null hypothesis significance testing (NHST) together with Bayesian analysis (in the form of Bayes factors). The analysis consisted of a series of one-way between-subjects analysis of variance (ANOVA) tests. For all tests, the independent categorical variable was *state of mind*, with three levels (mindfulness vs. mind-wandering vs. join-the-dots).

For the NHST tests, omnibus ANOVAs were followed by Tukey's honestly significant difference (HSD) pairwise comparisons, with criterion for significance set at α = 0.05. Although we present all of these tests for completeness, we only interpret the HSD tests when there was a significant omnibus ANOVA. The Bayesian analyses used default Bayes factor tests for ANOVA designs (Rouder et al., 2017) using the BayesFactor R package (Morey & Rouder, 2018). There were three model comparisons that were conducted using Bayes factors. The first model comparison was a *null* model (i.e., where all three levels of the design are equal) against a *full* model (i.e., where all three levels are not equal), denoted by $BF_{Null/Full}$. This model comparison allows quantification of the degree of support for "some effect" vs. "no effect". Another model—the *order restricted* model— is then constructed. In contrast to the full, unrestricted, model, where all levels of the design are assumed to be different, order restricted models test whether the data fit a predicted ordering of the factor level effects (e.g., mindfulness score is greater than the join-the dots score, which in turn is greater than the mind-wandering condition; i.e., mindfulness > join-the-dots > mind-wandering). In a second model comparison then, this order-restricted model is compared against the full (un-restricted) model; this model comparison—denoted by $BF_{Restricted/Full}$—allows quantification of the degree of support for "a specifically ordered (and predicted) effect" vs. "some (unrestricted) effect". Thus, in the presence of an effect, this model comparison allows us to test whether the ordering of the factor levels match our pre-registered hypotheses. The third model comparison—$BF_{Restricted/Null}$—compares the order restricted model against the null model. This model comparison allows us to compare a null model to a model capturing our pre-registered hypotheses. We followed the recommendations set out by Morey (2015) for testing the order restricted models using the Bayes factor package.

Note that a Bayes factor for model comparison between Model X and Model Y—denoted by $BF_{ModelX/ModelY}$—the evidence in favour of Model X is given by $BF_{ModelX/ModelY}$ itself, whereas the evidence for model Y is given as the inverse of this (i.e., $BF_{ModelY/ModelX}$ = 1 / $BF_{ModelX/ModelY}$). The reader should take note of the ordering of the subscript of Bayes factor reporting to note which model the data are providing support for. We interpret Bayes factors between 1–3 as representing anecdotal evidence, between 3–10 as representing moderate evidence, between 10–30 as strong evidence, 30–100 as very strong evidence, and greater than 100 as extreme evidence (Lee & Wagenmakers, 2013).

Manipulation Checks

Before presenting the main analysis, we wanted to ascertain that our manipulations of mindfulness and mind-wandering worked by assessing their impact on SMS, TRI, and TUT scores. For the SMS scale and its components, we used difference scores as the dependent variable by subtracting the pre-manipulation score on the questionnaire from the post-manipulation score. The descriptive statistics for the manipulation checks are in Table 1. See the top-left panel of Figure 1 for standardised effect sizes of between-condition comparisons for all scales.

[Enter Table 1 about here]

For SMS-Total, there was an effect of state of mind, $F(2, 281) = 27.11$, $p<.001$, $\eta^2 = 0.16$, 95% CI [0.09, 0.24]; the Bayes factor supported the presence of an effect (i.e., the full model) compared to the null model, $BF_{Full/Null} = 5.01 \times 10^8$. Note that our planned post-hoc Bayesian model comparisons could not be conducted on these data. This is because the data generally did not conform to our order-restricted predictions because often there was no significant difference between mindfulness and mind-wandering, as we had in our predictions the constraint that they would always be at the extremes of each other. As such, no samples from the posterior distribution conformed with our predicted ordering of the factor levels, and as such a value of zero enters the denominator of the Bayes factor test, producing a division including zero (which cannot be calculated meaningfully without incurring infinities). However, as outlined by a reviewer, entering such a model that is clearly wrong into formal model comparisons is likely not very informative. Tukey's HSD tests showed no significant difference between the mindfulness and mind-wandering conditions (p = .394), but both mindfulness (p<.0001) and mind-wandering (p<.001) were greater than the join-the-dots condition.

A similar pattern of results was found for SMS-Mind, $F(2, 281) = 23.90$, $p<.001$, $\eta^2 = 0.15$, 95% CI [0.07, 0.22], $BF_{Full/Null} = 3.71 \times 10^7$, where there was no significant difference between mindfulness and mind-wandering (p = .843), but both mindfulness (p<.0001) and mind-wandering (p<.0001) were greater than the join-the-dots condition. For SMS-Body, there was again an effect of state of mind, $F(2, 281) = 27.81$, $p<.001$, $\eta^2 = 0.17$, 95% CI [0.09, 0.24], $BF_{Full/Null} = 8.72 \times 10^8$, but all comparisons were now significant: mindfulness was greater than mind-wandering (p<.0001), mindfulness was greater than join-the-dots (p<.0001), and mind-wandering was also greater than join-the-dots (p=.016).

For the TRI questionnaire, there was a significant effect of state of mind, $F(2, 281) = 27.54$, $p<.001$, $\eta^2 = 0.16$, 95% CI [0.09, 0.24], $BF_{Full/Null} = 7.07 \times 10^8$. There was no significant difference between mindfulness and mind-wandering (p=.987), but mindfulness was lower than join-the-dots (p<.001), and mind-wandering was also lower than join-the-dots (p<.001). The TUT questionnaire also exhibited a significant effect of state of mind, $F(2, 281) = 35.18$, $p<.001$, $\eta^2 = 0.20$, 95% CI [0.12, 0.28], $BF_{Full/Null} = 2.99 \times 10^{11}$. Mindfulness was significantly lower than mind-wandering ($p<.001$), mindfulness was greater than join-the-dots ($p=.003$), and mind-wandering was also greater than join-the-dots ($p<.001$).

Effects on Memory

In this section, we present the results on the effects of state of mind on correct and false memory for both recognition and recall data. The descriptive statistics for all tests are shown in Table 2. For ease of exposition, we present the ANOVA results for all tests in Table 3, and the Bayesian model comparison results in Table 4. Plots of standardised effect sizes for all between-condition comparisons can be seen in Figure 1.

[Insert Figure 1 about here]

[Enter Table 2 about here]

[Enter Table 3 about here]

[Enter Table 4 about here]

For the recognition data, the NHST analysis showed no significant effects of state of mind on any of the measures of correct or false memories (lowest *p*-value = 0.077). For all of these tests, the Bayesian model comparison $BF_{Null/Full}$ favoured the null model: for the measure *Total, Correct Recognition* the evidence in favour of the null model compared to the full model was only anecdotal; for all other measures, the $BF_{Null/Full}$ was either moderate (*Remember, Correct Recognition; Know, False Recognition*) or strong (all others). We also found that the null model was preferred against our order-restricted models—that is, $BF_{Null/Restricted}$—in all cases; for *Remember, Filler* and *Know, False Recognition* the evidence for this preference was moderate, but it was strong in all other cases. Thus, in summary, we find no evidence for an effect of state of mind on any measures of correct or false recognition memory.

For the free recall data, a similar picture emerged. The NHST analysis showed no significant effect of state of mind for either correct or false recall. The Bayesian model comparison $BF_{Null/Full}$ provided moderate support for the null model in both cases. For the order-restricted tests, the correct recall data was better predicted by the null model, but only at anecdotal levels, $BF_{Null/Restricted} = 2.34$. The null model was a much better predictor of the data than the restricted model, $BF_{Null/Restricted} = 15.62$, which is strong evidence in favour of the null model.[2]

Discussion

In summary, the state of mind inductions worked: The mindfulness induction induced mindfulness, and the mind-wandering induction induced mind-wandering. However, there was no evidence of a difference in the levels of either correct or false memory for recall or recognition between the mindfulness, mind-wandering, or join-the-dots conditions. Thus, none of our hypotheses were supported; furthermore, neither were the previous findings by Wilson et al. (2015, Experiment 1) or Rosenstreich (2016, Experiment 2) who found that mindfulness increased false memories. Instead, our findings are consistent with Baranski and Was (2017) who also found no evidence for a difference in either true or false recall or recognition memory performance between mindfulness and mind-wandering conditions in their first experiment, or in false recall between the conditions in their second experiment which included a join-the-dots condition. One explanation for the discrepant findings across

[2] In Supplementary Material C we present exploratory analyses assessing the extent to which an individual's score on the state of mind measures predicted their memory performance irrespective of condition.

the five experiments is that the brief inductions used (all 15 minutes, except for Rosenstreich, 2016, Experiment 2, who used 30 minutes) were not sufficient to consistently induce the relevant state of mind to last throughout the subsequent tasks. Possibly the inductions are not long enough, or one-off brief mindfulness manipulations—unless used with experienced meditators—may not just increase mindfulness. Furthermore, we used a double-blind procedure whereby the experimenters did not know which condition participants were allocated to. Gilder and Heerey (2018) demonstrated the impact of a non-double-blind procedure on performance. It is unclear whether Wilson et al (2015) used such a procedure for their Experiment 1 (they did in Experiment 2) or whether Baranski and Was (2018) or Rosenstreich (2016) did and any impact such variance in procedures may have had.

One key methodological difference between our study and previous research was our use of manipulation checks to ensure the manipulations induced the state of mind they claimed to. Despite the effectiveness of the inductions, there are additional findings to consider. First, not only did the mindfulness manipulation induce mindfulness, so too did the mind-wandering manipulation, with higher scores post-induction for the overall SMS and mind subscale. The join-the-dots condition, by comparison, did not induce mindfulness on any of the scales. Second, the mindfulness induction also induced mind-wandering, with higher scores post-induction for both TRI and TUT. This is perhaps not surprising since this brief mindfulness induction was likely the first exposure to mindfulness for many participants, and mind-wandering is more prevalent in novice meditators (Lutz, Slagter, Dunne, & Davidson, 2008). The join-the-dots condition also induced mind-wandering, although only on the TRI and not on the TUT scale. Third, there was no significant difference between the mindfulness and mind-wandering inductions on the overall SMS, the mind subscale, or the TRI scales. Previous research contrasting mindfulness and mind-wandering (e.g., Mrazek, Smallwood, & Schooler, 2012) has focused on dispositional mindfulness, whereas brief mindfulness inductions induce state mindfulness. It is possible that mind-wandering might not be the appropriate control condition for state mindfulness studies given the likely use of novice meditators and it may instead be that the join-the-dots activity or similar might be able to differentiate more clearly between the components at play during state mindfulness induced through a brief induction, since join-the-dots increased mind-wandering but not mindfulness.

There are two potential problems with measuring states of mind: first, it is possible that demand characteristics distort the measurements; second, it is possible that the manipulation may have worn off by the time the questionnaires were completed and the DRM lists were presented. However, as outlined in the introduction, it is not very satisfactory to assume that brief manipulations are sufficient to induce mindfulness and/or mind-wandering and we would further posit that there is not yet sufficient evidence to indicate that brief mindfulness and mind-wandering instructions do activate different states of mind. Further research is needed to address the longevity and nature of the states of mind induced by brief manipulations.

To conclude, more research is needed into the best control condition to use for state mindfulness research. Our results are consistent with Baranksi and Was (2017), finding no evidence for a difference in false memory susceptibility between mindfulness, mind-wandering and join-the-dots conditions. This suggests that it is too soon to say that “mindfulness plays havoc with memory” (Telegraph, 2015).

Open Practices Statement

The experiment reported here was pre-registered on the Open Science Framework (https://osf.io/ebhdb). All study materials, raw data, and the analysis code can be found on the Open Science Framework (https://osf.io/4kmf8/).

Author contributions

D. S. Lindsay offered S. M. Sherman the opportunity to conduct a replication study. Both authors contributed to the study design & pre-registration protocol, with guidance from D. S. Lindsay. Testing and data collection were performed by our research assistants, L. James, H. Gilman and C. Bagnall. S. M. Sherman prepared the data for analysis. J. A. Grange performed the data analysis and S. M. Sherman & J. A. Grange provided interpretation. Both authors drafted the manuscript and approved the final version of the manuscript for submission.

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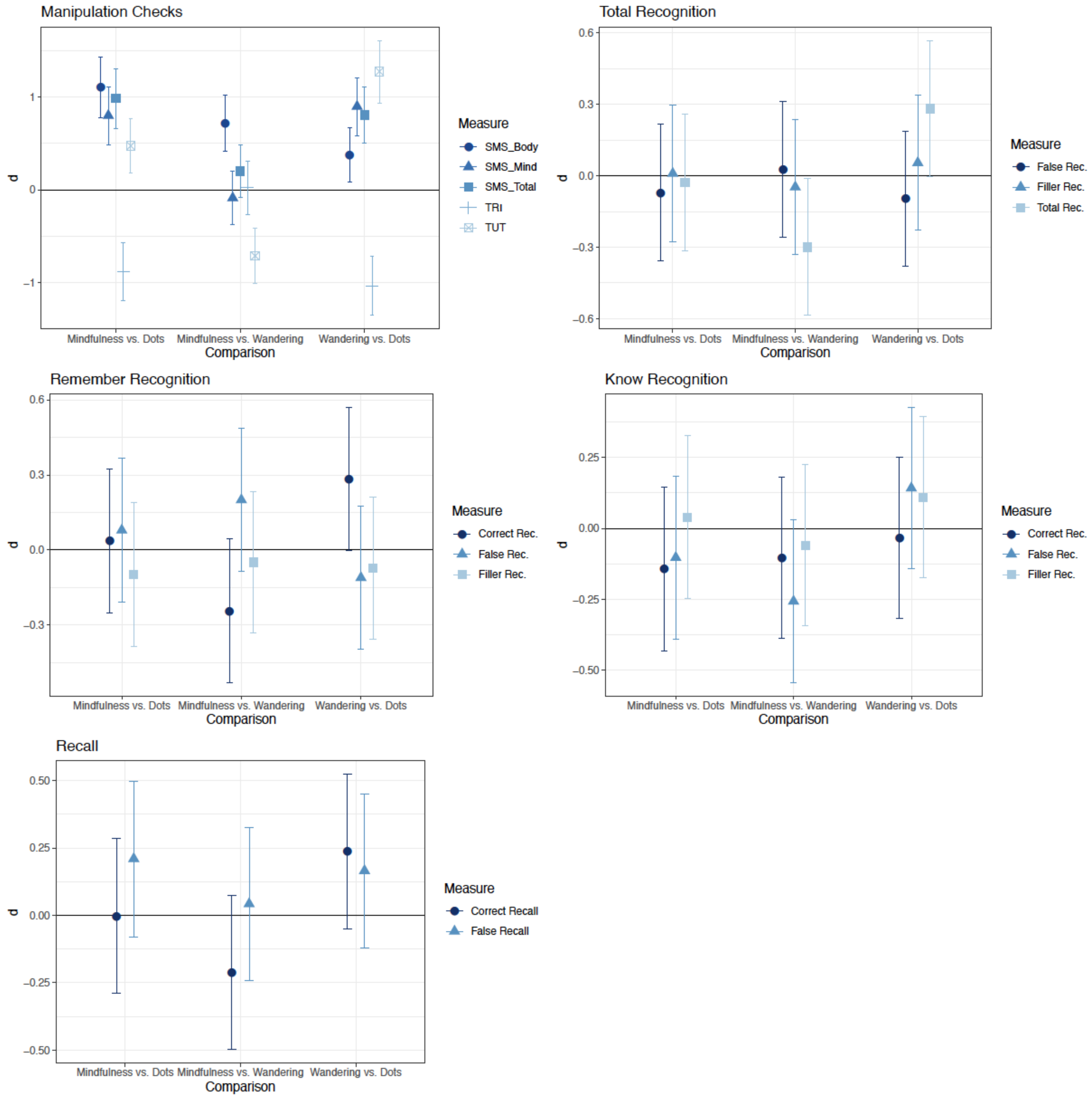

Figure 1. Standardised effect size estimates (Cohen's *d*, with the associated 95% confidence intervals of each point estimate as error bars) for all between-condition pairwise comparisons for manipulation checks and for all measures of memory performance.

Table 1. Mean values for the manipulation checks across all three conditions. The standard errors of the mean estimates are in parentheses.

Measure	Condition		
	Mindfulness	**Mind-Wandering**	**Join-the-Dots**
SMS (Total)[a]	15.8 (1.52)	12.8 (1.46)	0.11 (1.77)
SMS (Mind)[a]	11.1 (1.15)	12.0 (1.07)	1.6 (1.32)
SMS (Body)[a]	4.66 (0.50)	0.79 (0.60)	-1.49 (0.64)
TRI	18.2 (0.76)	18.1 (0.57)	24.3 (0.64)
TUT	19.0 (0.82)	24.1 (0.68)	15.7 (0.74)

Note. SMS = State Mindfulness Scale (21 items scored on 5 point scale); TRI = Task-related interference scale (8 items scored on 5 point scale); TUT = Task-unrelated thoughts scale (8 items scored on 5 point scale).
[a] = The scores for these measures reflect difference scores (post-manipulation score minus pre-manipulation score).

Table 2. Mean proportion scores for the data for all dependent variables (DVs) across all three conditions. The standard errors of the mean estimates are in parentheses.

DV	Condition		
	Mindfulness	**Mind-Wandering**	**Join-the-Dots**
Total Correct Recognition[a]	0.74 (0.02)	0.78 (0.01)	0.74 (0.54)
Total False Recognition[b]	0.73 (0.02)	0.73 (0.02)	0.75 (0.02)
Total Filler	0.12 (0.01)	0.13 (0.01)	0.12 (0.02)
Remember Correct Recognition[a]	0.50 (0.02)	0.54 (0.02)	0.49 (0.02)
Remember False Recognition[b]	0.40 (0.03)	0.35 (0.03)	0.38 (0.03)
Remember Filler	0.34 (0.11)	0.40 (0.11)	0.54 (0.26)
Know Correct Recognition[a]	0.17 (0.01)	0.18 (0.01)	0.18 (0.01)
Know False Recognition[b]	0.25 (0.02)	0.29 (0.02)	0.27 (0.02)
Know Filler	0.05 (0.01)	0.05 (0.01)	0.04 (0.01)
Correct Recall[a]	0.51 (0.01)	0.53 (0.01)	0.51 (0.01)
False Recall[b]	0.37 (0.02)	0.37 (0.02)	0.33 (0.02)

Note: a = Correct recognition/recall refers to the correct recognition of list items. b = False recognition/recall refers to the false recognition of critical lure items.

Table 3. Null hypothesis significance tests of the effect of state-of-mind on different measures of memory.

Memory Measure	Omnibus ANOVA	Tukey's HSD *p*-values		
		M vs MW	**M vs JtD**	**MW vs JtD**
Total Correct Recognition[a]	$F(2, 281) = 2.58$, p=.077, $\eta^2 = 0.02$, 95%CI [0, 0.06]	.101	.977	.156
Total False Recognition[b]	$F(2, 281) = 0.24$, p=.789, η^2 <0.01, 95%CI [<0.01, 0.02]	.980	.883	.781
Total Filler	$F(2, 281) = 0.08$, p=.923, η^2 <0.01, 95%CI [<0.01, 0.001]	.949	.998	.926
Remember Correct Recognition[a]	$F(2, 281) = 2.20$, p=.113, $\eta^2 = 0.02$, 95%CI [0, 0.05]	.220	.965	.134
Remember False Recognition[b]	$F(2, 281) = 0.89$, p=.412, η^2 <0.01, 95%CI [<0.01, 0.03]	.381	.847	.722
Remember Filler	$F(2, 281) = 0.31$, p=.733, η^2 <0.01, 95%CI [<0.01, 0.02]	.975	.726	.843
Know Correct Recognition[a]	$F(2, 281) = 0.46$, p=.630, η^2 <0.01, 95%CI [<.001, 0.02]	.769	.623	.966
Know False Recognition[b]	$F(2, 281) = 1.49$, p=.226, $\eta^2 = 0.01$, 95%CI [0, 0.04]	.206	.776	.560
Know Filler Recognition	$F(2, 281) = 0.24$, p=.784, $\eta^2 = 0.15$, 95%CI [0, 0.02]	.916	.954	.767
Correct Recall	$F(2, 281) = 1.60$, p=.203, $\eta^2 = 0.01$, 95%CI [0, 0.04]	.269	.999	.276
False Recall	$F(2, 281) = 1.13$, p=.325, $\eta^2 = 0.01$, 95%CI [0, 0.04]	.954	.332	.487

Note. M = Mindfulness; MW = Mind-wandering; JtD = join-the-dots. CI = 95% Confidence Interval of eta squared effect size estimate. HSD = Tukey's honestly significant difference post-hoc comparisons (note that these are only interpretable in the event of a significant omnibus ANOVA result).
a = Correct recognition refers to the correct recognition of list items. b = False recognition refers to the false recognition of critical lure items.

Table 4. Bayes factors for all model comparisons for the different memory measures. In a model comparison of Model X vs. Model Y, a Bayes factor larger than one indicates support for Model X; a Bayes factor lower than 1 indicates support for Model Y.

	Model Comparison		
Memory Measure	**Null vs. Full**	**Full vs. Restricted**	**Null vs. Restricted**
Total Correct Recognition	2.56	62.50	166.67
Total False Recognition	21.28	1.47	31.25
Total Filler	24.39	0.75	18.52
Remember Correct Recognition	3.62	31.25	111.11
Remember False Recognition	11.76	3.75	43.48
Remember Filler	20.00	0.49	9.71
Know Correct Recognition	17.54	3.07	52.63
Know False Recognition	6.85	0.68	4.63
Know Filler Recognition	21.28	0.75	15.87
Correct Recall	6.21	0.38	2.34
False Recall	9.52	1.64	15.62

Note. a = Mindfulness > Join-the-dots > Mind wandering; b = Mind wandering > Join-the-dots > Mindfulness; c = Join-the-dots > Mind wandering > Mindfulness;

Sherman & Grange

Exploring the Impact of Mindfulness on False Memory Susceptibility

Supplementary Material

Contents:

Supplementary Material A: Power Sensitivity Analysis

We conducted a power sensitivity analysis using the pwr package in R. Given our final sample size of N = 287 (n per group = 95, rounding down), we explored the smallest effect size detectable given a range of power criteria (from 0.75 to 1.0). The code for the sensitivity analysis can be found in the main analysis file of the manuscript, and the results of the analysis can be seen in Figure A1. As can be seen, our final sample size had 80% power to detect an effect size as small as f = 0.235, 90% power to detect an effect as small as f = 0.212, and 80% power to detect an effect as small as f = 0.185.

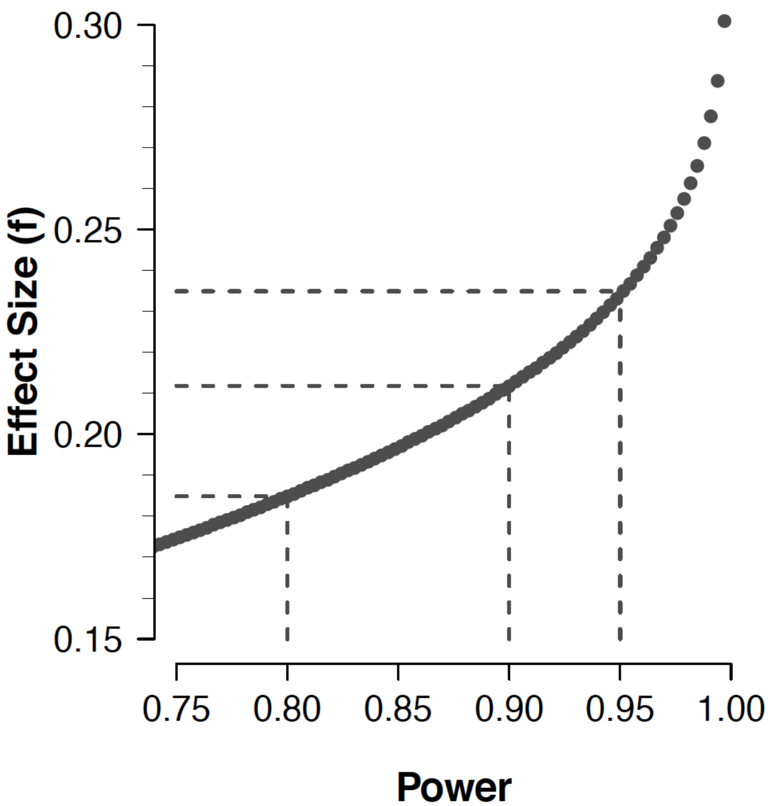

Figure A1. Plot of the power sensitivity analysis. Dotted lines show detectable effect sizes for power criteria of 80%, 90%, and 95%.

Supplementary Material B: Pre-Registered Follow-Up Analyses

In this section we report supplementary analyses that formed part of our original pre-registration (see Section 20 of pre-registration document). These analyses were not central to our main research questions, but were additional analyses that we thought would be interesting to conduct (and hence to pre-register).

Omnibus Tests Adding Change in Mindfulness and Mind-Wandering as Covariate

We repeated our omnibus frequentist tests of the effect of mind-states on memory whilst entering individual measures of mind-states as covariates. Specifically, in a first re-analysis we entered individual participants' change in mindfulness scores (i.e., post-induction SMS total score minus pre-induction SMS total score) as a covariate. In a second set of re-analyses, we entered individual measures of mind-wandering (as measured by the TRI and the TUT, analysed separately) as covariates.

The analysis consisted of a set of linear regressions (one for each measure of memory performance) with the dependent variable predicted from condition (i.e., mind-manipulation) and the relevant covariate. The results of these analyses are shown in Table B1 overleaf.

None of these analyses produced results that qualitatively differed from those reported in the main manuscript.

Table B1. Beta estimates from regression analyses for the effect of state-of-mind (condition) on different measures of memory with change in mindfulness (as assessed by the SMS Total; i.e., post-induction score minus pre-induction score) as a covariate and mind-wandering score as covariate.

Memory Measure	Mindfulness Change as Covariate	Mind-Wandering (TRI) as Covariate	Mind-Wandering (TUT) as Covariate
Total Correct Recognition	*β* Condition = 0.262, *t* = 0.659, *p*=.510	*β* Condition = 0.485, *t* = 1.256, *p*=.210	*β* Condition = 0.089, *t* = 0.238, *p*=.812
Total False Recognition	*β* Condition = 0.178, *t* = 0.860, *p*=.391	*β* Condition = 0.168, *t* = 0.820, *p*=.413	*β* Condition = 0.115, *t* = 0.589, *p*=.556
Total Filler	*β* Condition = 0.087, *t* = 0.334, *p*=.738	*β* Condition = 0.006, *t* = 0.023, *p*=.982	*β* Condition = 0.057, *t* = 0.236, *p*=.813
Remember Correct Recognition	*β* Condition = -0.195, *t* = -0.403, *p*=.688	*β* Condition = 0.176, *t* = 0.370, *p*=.712	*β* Condition = -0.056, *t* = -0.123, *p*=.902
Remember False Recognition	*β* Condition = -0.158, *t* = -0.650, *p*=.516	*β* Condition = -0.094, *t* = -0.393, *p*=.695	*β* Condition = -0.142, *t* = -0.619, *p*=.536
Remember Filler	*β* Condition = 0.042, *t* = 0.307, *p*=.759	*β* Condition = 0.065, *t* = 0.481, *p*=.631	*β* Condition = 0.119, *t* = 0.928, *p*=.354
Know Correct Recognition	*β* Condition = 0.389, *t* = 1.270, *p*=.205	*β* Condition = 0.381, *t* = 1.263, *p*=.208	*β* Condition = 0.215, *t* = 0.746, *p*=.456
Know False Recognition	*β* Condition = 0.124, *t* = 0.757, *p*=.450	*β* Condition = 0.128, *t* = 0.793, *p*=.428	*β* Condition = 0.147, *t* = 0.964, *p*=.336
Know Filler Recognition	*β* Condition = 0.054, *t* = 0.339, *p*=.735	*β* Condition = -0.035, *t* =-0.222, *p*=.825	*β* Condition = -0.025, *t* = -0.166, *p*=.868
Correct Recall	*β* Condition = -0.362, *t* = -0.250, *p*=.803	*β* Condition = 1.056, *t* = 0.745, *p*=.457	*β* Condition = -0.252, *t* = -0.185, *p*=.853
False Recall	*β* Condition = -0.252, *t* = -1.308, *p*=.192	*β* Condition = -0.225, *t* = -1.186, *p*=.236	*β* Condition = -0.296, *t* = -1.639, *p*=.102

Note. M = Mindfulness; MW = Mind-wandering; JtD = join-the-dots.

Removal of Participants Showing No Effect of Induction

In this analysis, we were interested in exploring what effect removing participants who do not show the expected change in mindfulness score after the induction phase would have on our analyses. Specifically, we repeated our omnibus frequentist tests of the effect of mind-states on memory, but removed participants who did not show a change in mindfulness score in the expected direction; that is, removing participants in the mindfulness condition who showed *no change* or a *decrease* in mindfulness, and removing participants in the mind-wandering & control conditions who showed an *increase* in mindfulness.

In the mindfulness condition, 7 participants showed either no change in mindfulness after induction, or *reduced* measures of mindfulness after induction. In the other two conditions, there were 128 participants who showed an increase in mindfulness after a non-mindfulness induction. The range of these changes in mindfulness was 1–71 (Mean = 15.59, Median = 13.00, SD = 11.99). As suggested in the main manuscript, the vast majority of these participants (N = 81, 63.28%) were in the mind-wandering condition, suggesting mind-wandering also induced mindfulness to some degree.

Note that our pre-registered analysis is likely not informative to perform in hindsight as removal of almost all participants from the mind-wandering condition due to the above exclusion plan would leave us with a severely unbalanced design. We therefore decided not to conduct this planned analysis.

Assessing Longevity of Induction

In our pre-registration document, we stated that we would attempt to assess the longevity of any impact of the mind manipulations. To do this, we stated that we would:

...compare performance on early lists (lists 1-3) to late lists (10-12). This will be achieved by conducting a 2 (mean correct recall on lists 1-3, mean correct recall on lists 10-12) x 3 (mind-wandering, mindfulness, neutral) ANOVA followed with orthogonal planned contrasts if omnibus ANOVA suggests this is required. If the effect of the mind manipulations is wearing off we would expect correct recall to decrease from lists 1-3 to lists 10-12 in the mindfulness condition, to stay the same in the neutral condition and to either stay the same or increase in the mind-wandering condition.

However, we were unfortunately unable to complete this analysis. The order of list presentation was counterbalanced in our study, and we mistakenly didn’t add a marker to indicate which list order participants were exposed to, and hence cannot identify in the raw data early and late lists.

Supplementary Material C: ExploratoryAnalysis

In non-pre-registered analysis we wished to explore the extent to which an individual's score on the state of mind measures—regardless of manipulation condition they were in—predicted their memory performance for both correct and false memories in recognition and recall for the total scores. We therefore performed a series of linear regressions predicting memory performance from questionnaire scores. For the SMS scales, we used the post-induction score as the predictor. The outcome of these regressions are shown in Table C1.

We found that TRI negatively predicted correct recognition (p=.005). False recognition was positively predicted by both SMS-Total (p=.040) and SMS-Mind (p=.040) scores. For recall data, correct recognition was predicted by TRI scores (p=.048). False recall was negatively predicted by SMS-Total (p=.045) and SMS-Body (p=.015) scores.

Although some caution is required around strong interpretations of these findings—after all, we have not controlled for multiple tests, some of the p-values are only just beneath the classical criterion for significance, and the analysis was not pre-registered—that we find a similar pattern across both measures of memory (i.e., recognition and recall) provides a tentative suggestion that—regardless of the manipulation—one's state of mind is related to memory performance: higher levels of mindfulness tend to be associated with higher levels of false memory; higher levels of mind-wandering (as measured by the TRI, at least) are associated with lower levels of correct memory.

Table C1. Regressions exploring the relationship between questionnaire scores (post-induction scores for the SMS) and correct (list total) and false (lure total) memories for both recognition and free recall response data.

Memory Task	Model	$\beta_{MEASURE}$	*t*	*p*
Recognition	List Total ~ SMS Total	0.002	0.105	0.917
	List Total ~ SMS Mind	0.020	0.753	0.452
	List Total ~ SMS Body	-0.072	-1.277	0.203
	List Total ~ TRI	**-0.118**	**-2.815**	**0.005**
	List Total ~ TUT	0.006	0.168	0.867
	Lure Total ~ SMS Total	**0.021**	**2.067**	**0.040**
	Lure Total ~ SMS Mind	**0.029**	**2.063**	**0.040**
	Lure Total ~ SMS Body	0.047	1.577	0.116
	Lure Total ~ TRI	-0.019	-0.854	0.394
	Lure Total ~ TUT	0.011	0.588	0.557
Recall	List Total ~ SMS Total	-0.069	-0.957	0.339
	List Total ~ SMS Mind	-0.064	-0.643	0.521
	List Total ~ SMS Body	-0.286	-1.388	0.166
	List Total ~ TRI	**-0.304**	**-1.982**	**0.048**
	List Total ~ TUT	-0.151	-1.118	0.265
	Lure Total ~ SMS Total	**0.019**	**2.010**	**0.045**
	Lure Total ~ SMS Mind	0.026	1.572	0.117
	Lure Total ~ SMS Body	**0.067**	**2.445**	**0.015**
	Lure Total ~ TRI	-0.018	-0.885	0.377
	Lure Total ~ TUT	-0.019	-1.066	0.287

Note. SMS = State Mindfulness Scale; TRI = Task-related interference scale; TUT = Task-unrelated thoughts scale. "~" can be read as "predicted by"; the response variable in each model is on the left of each tilde, and the independent (predictor) variable is on the right.

Exploring the Impact of Mindfulness on False Memory Susceptibility

Transparency Report 1.0 (full, 36 items)

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10 March, 2020

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Link to Project Repository: https://osf.io/4kmf8/

PREREGISTRATION SECTION

(1) Prior to analyzing the complete data set, a time-stamped preregistration was posted in an independent, third-party registry for the data analysis plan. **Yes**

(2) The manuscript includes a URL to all preregistrations that concern the present study. **Yes**

(3) The study was preregistered… **before any data were collected**

The preregistration fully describes…

(4) all inclusion and exclusion criteria for participation (e.g., English speakers who achieved a certain cutoff score in a language test). **Yes**

(5) all procedures for assigning participants to conditions. **Yes**

(6) all procedures for randomizing stimulus materials. **Yes**

(7) any procedures for ensuring that participants, experimenters, and data-analysts were kept naive (blinded) to potentially biasing information. **Yes**

(8) a rationale for the sample size used (e.g., an a priori power analysis). **Yes**

(9) the measures of interest (e.g., friendliness). **Yes**

(10) all operationalizations for the measures of interest (e.g., a questionnaire measuring friendliness). **Yes**

(11) the data preprocessing plans (e.g., transformed, cleaned, normalized, smoothed). **Yes**

(12) how missing data (e.g., dropouts) were planned to be handled. **Yes**

(13) the intended statistical analysis for each research question (this may require, for example, information about the sidedness of the tests, inference criteria, corrections for multiple testing, model selection criteria, prior distributions etc.). **Yes**

Comments about your Preregistration

The pre-registration itself can be found here: https://osf.io/ebhdb

METHODS SECTION

The manuscript fully describes...

(14) the rationale for the sample size used (e.g., an a priori power analysis). **Yes**

(15) how participants were recruited. **Yes**

(16) how participants were selected (e.g., eligibility criteria). **Yes**

(17) what compensation was offered for participation. **Yes**

(18) how participant dropout was handled (e.g., replaced, omitted, etc). **Yes**

(19) how participants were assigned to conditions. **Yes**

(20) how stimulus materials were randomized. **Yes**

(21) whether (and, if so, how) participants, experimenters, and data-analysts were kept naive to potentially biasing information. **Yes**

(22) the study design, procedures, and materials to allow independent replication. **Yes**

(23) the measures of interest (e.g., friendliness). **Yes**

(24) all operationalizations for the measures of interest (e.g., a questionnaire measuring friendliness). **Yes**

(25) any changes to the preregistration (such as changes in eligibility criteria, group membership cutoffs, or experimental procedures)? **Yes**

Comments about your Methods section

No comments.

RESULTS AND DISCUSSION SECTION

The manuscript...

(26) distinguishes explicitly between "confirmatory" (i.e., prespecified) and "exploratory" (i.e., not prespecified) analyses. **Yes**

(27) describes how violations of statistical assumptions were handled. **No**

(28) justifies all statistical choices (e.g., including or excluding covariates; applying or not applying transformations; use of multi-level models vs. ANOVA). **Yes**

(29) reports the sample size for each cell of the design. **Yes**

(30) reports how incomplete or missing data were handled. **Yes**

(31) presents protocols for data preprocessing (e.g., cleaning, discarding of cases and items, normalizing, smoothing, artifact correction). **Yes**

Comments about your Results and Discussion

No comments.

DATA, CODE, AND MATERIALS AVAILABILITY SECTION

The following have been made publicly available...

(32) the (processed) data, on which the analyses of the manuscript were based. **Yes**

(33) all code and software (that is not copyright protected). **Yes**

(34) all instructions, stimuli, and test materials (that are not copyright protected). **Yes**

(35) Are the data properly archived (i.e., would a graduate student with relevant background knowledge be able to identify each variable and reproduce the analysis)? **Yes**

(36) The manuscript includes a statement concerning the availability and location of all research items, including data, materials, and code relevant to the study. **Yes**

Comments about your Data, Code, and Materials

No comments.