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Two independent sources of difficulty in perspective-taking/theory of mind tasks.

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Abstract

Many perspective-taking and theory of mind tasks require participants to pass over the answer that is optimal from the self-perspective. For instance, in the classic change-of-location (false belief) task participants are required to ignore where they know the object to be, and in the Director Task participants are required to ignore the best match for the instruction the other, less knowledgeable agent gives them (e.g. 'the top cup'). However, a second but equally critical requirement in such tasks is the ability to select a response which is *wrong* from the self-perspective; where the object is *not*, or an object that does *not* match the instruction (e.g. the middle cup instead of the top cup from one's own perspective). We present the results of an experiment that teases apart these two effects and demonstrate that both contribute independently to the difficulty in taking other perspectives to our own. Re-analyses of data from previous experiments confirm this dual effect. These results suggest a revision of our understanding of egocentricity and difficulty in perspective-taking generally.

The ability to take other people's perspectives is integral to communication and effective interaction with other agents (Clark & Brennan, 1991; Sperber & Wilson, 1987). Both children and adults, however, experience difficulty in appreciating that other agents see the world differently (Epley, Morewedge, & Keysar, 2004; Keysar, Lin, & Barr, 2003). Such difficulties have usually been attributed to the tendency to be biased by one's own perspective when reasoning about others', an effect known as the curse of knowledge (Birch & Bloom, 2004), the curse of expertise, (Hinds, 1999), the false consensus effect (Ross, Greene, & House, 1977), and egocentrism or egocentric bias (Apperly et al., 2010; Epley et al., 2004; Keysar, Barr, Balin, & Brauner, 2000), among other terms.

This bias towards our own knowledge can be a hindrance when attempting to be objective about other people's beliefs and experiences (Risen & Critcher, 2011). Typical means of measuring this bias are tasks in which participants are instructed to select a target that is not optimal or 'true' from their own perspective but appears to be true from the agent's (Dennett, 1978; Keysar et al., 2000; Wimmer & Perner, 1983). Deviation towards the egocentrically correct distractor, or delays in processing the correct answer relative to when there is no egocentrically correct distractor present, are usually considered to index bias. For instance, in the Director Task (Keysar et al., 2003) participants are directed by the agent to select objects in an array. When the agent has a restricted view of the objects, the command from the agent to select the 'top cup' requires the participant to select a cup which from their own perspective is the *middle* cup, rather than the actual top cup which is hidden from the agent's view. It has been shown that adults make more errors and perform more slowly when there is a better match for the instruction from the participant's own perspective (Apperly et al., 2010; Keysar et al., 2003; Legg, Olivier, Samuel, Lurz, & Clayton, 2017; Samuel, Roehr-Brackin, Jelbert, & Clayton, 2019; Wu & Keysar, 2007).

Testing participants' ability to reason about other perspectives in the presence of an egocentric distractor, which we here term the 'right distractor', is at the heart of the classic change-of-location/false belief task. In this task, participants are instructed to select the location that another agent falsely believes an object to be, contrary to the participant's own knowledge of its true whereabouts (Baron-Cohen, Leslie, & Frith, 1985; Wellman, Cross, & Watson, 2001; Wimmer &

Perner, 1983). Overall, much of our understanding of theory of mind, which is the ability to represent others' unobservable mental states (Premack & Woodruff, 1978), as well as our understanding of our tendency to be egocentric more generally (Apperly et al., 2010; Birch & Bloom, 2007; Keysar et al., 2003), is predicated upon this 'right distractor' paradigm.

A problem at the core of these paradigms is that they conflate the difficulty of ignoring the egocentrically correct distractor with the difficulty voluntarily selecting something that is egocentrically *wrong*. For example, in the Director Task the highest cup in the grid is the right distractor and must be ignored, but the middle cup is a 'wrong target' and must be selected. In the classic false belief task, the participant must select the location they know the items *not* to be in. Indeed, if both the right distractor *and* the wrong target problem are not solved, then either a 'distractor error' or no response at all (a timeout perhaps) will occur.

The reason for this conflation of two problems is that it is hard to design a task that can independently manipulate these two phenomena from the same perspective. Simply put, if there is a right distractor then the target must be 'wrong', and vice-versa. However, until we can understand what interferes with participants' correct choices on such tasks, we cannot know precisely what the difficulty in making judgments about other perspectives is. Is it the lure of what we think is correct, the desire to avoid error, or both?

One way to circumvent this issue is to utilise bivalent stimuli which change identity according to perspective, such as the way a 6 appears to be a 9 when it is viewed upside-down. By doing so, it becomes possible to manipulate not only whether there is a right distractor but also whether there is a 'wrong' target. A recent visual perspective-taking paradigm developed by Samuel, Legg, Manchester, Lurz, and Clayton (2019) presents an opportunity to do this. In the top left image of Figure 1 the avatar (seen above the grid) says 'four', and the participant is required to locate the four from the perspective of the avatar. The correct answer is a bottom-left response key, corresponding to the bottom-left square. The original version of the task was concerned with the nature of participant's responses, namely if they would erroneously press the button consistent not with their own perspective but with the avatar's. Additionally, the avatar could appear at any of the four edges of the

grid, creating shared-, left, right-, and opposite-perspective trials. In the present study we were interested in opposite perspective trials specifically. This is because difficulty on trials from this perspective can be caused by either the pull of the egocentrically correct ‘right distractor’, or the push of the egocentrically incorrect ‘wrong target’. We can pull apart these two effects by comparing performance in this baseline condition with the conditions shown bottom left (Contrast A) and top right (Contrast B). The right distractor contrast (Contrast A in the figure) compares performance in the baseline condition with a condition in which the distractor is not egocentrically correct and so minimises the right distractor effect (while keeping constant the wrong target effect). Similarly, the wrong target contrast (Contrast B in the figure) compares performance in the baseline condition with performance in which the target is identifiably another digit from the self-perspective. This condition maximises the wrong target effect (while keeping constant the right distractor effect). Results from the original version of this task pointed to an additional difficulty caused by the requirement to select a target identifiable as another number (9) relative to the upside-down 4 (Samuel, Legg, et al., 2019). In the present study, we used this task in order to examine whether these two effects contribute independently to the difficulty of performing the perspective-taking task.

It has often been suggested that domain-general executive functions might serve to reduce egocentric biases (Brown-Schmidt, 2009; Lin, Keysar, & Epley, 2010), but usually in the context of the understanding that egocentric biases result from the presence of right distractors, with executive functions serving potentially to reduce this bias. Immediately after the perspective-taking task we gave participants a Simon Task (Simon & Rudell, 1967), which provides a measure of the ability to inhibit distracting information known as the Simon Effect. By correlating the Simon Effect with the two effects of interest, we could check whether executive function does predict the ability to ignore right distractors or indeed wrong targets.

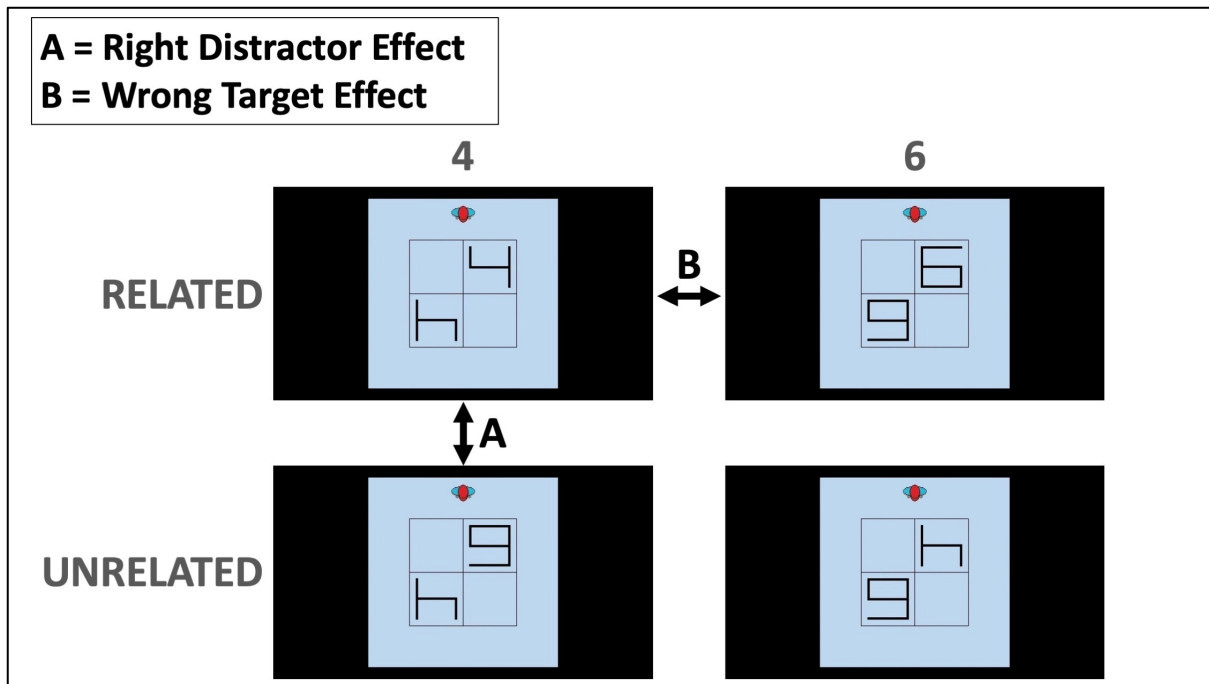


Figure 1. Example stimuli from the present experiment. Opposite perspective trials afforded four types of stimuli combinations. The top left grid illustrates an example in which there is a 'right distractor' (the 4 in the top right corner) and an ambiguous and thus only minimally wrong target (always an upside-down 4 from the participant's perspective). In the bottom left grid, the distractor is unrelated to the instruction to find the 4, and thus the difference between this grid and the one in the top right forms the Right Distractor Contrast (A), with trials where the distractor matches the instruction (the top left grid) predicted to be harder. Note that across this contrast the target is held constant. In the top right grid the target is maximally wrong because it is another number (always a 9) from the participant's perspective. The comparison in performance between grids like this and grids like that illustrated in the top left thus forms the Wrong Target Contrast (B), with trials where the target is maximally wrong (the top right grid) predicted to be harder. Note in this contrast the distractor is always a perfect match for the instruction from the egocentric perspective, holding the nature of the distractor constant. Although the diagonal arrangement of the digits within the grid varied, only these specific stimuli pairings were used to calculate the contrasts of interest, because they allowed a measurement of one effect while keeping the other constant. Shared-perspective trials in which the avatar was at the bottom of the grid, and grids with a target 6 and unrelated distractor (e.g. the bottom right example) did not form part of calculations of these two contrasts.

Method

Participants

We considered medium effect sizes the minimum of interest for the right distractor and wrong target effects (based on the contrasts shown in Fig 1, one-tailed). A power analysis using G*Power 3.1.9.5 found a 95% chance of detection required approximately 44 participants. All participants were required to be aged 18-35, be native English speakers, have normal or corrected-to-normal vision, and demonstrate a minimum 60% accuracy on the task (chance being 25%). Participants were recruited using the University of Essex online recruiting system and were compensated with course credit. Ethical approval was obtained from the University of Essex Science and Health Ethics Sub-Committee. Total participation time was approximately 30 minutes. We recruited 47 participants whom, after removals following accuracy checks, became $N = 43$ for the analyses ($M_{age} = 19$, range 18-24; 36 female, 6 male, 1 non-binary).

Materials and procedure

Perspective-taking task. Participants were instructed that they would hear a target number and that they should locate this number from an avatar's perspective and then press a button that corresponded to where they themselves saw it. For example, if the target was in the top right position in the grid from their perspective, the participant should press the top right button. They were told to respond as quickly as possible and to use the forefinger of their left hand for the left-sided buttons and the right hand for the right-sided buttons.

Each trial began with a blank (blue) screen and a cue (1000 ms) via headphones, which was always either 'four' or 'six' always spoken in a female voice (the avatar was described as female). 250 ms after the cue an empty 2 x 2 grid then appeared (100 ms) followed immediately by the avatar (wearing a red cap, seen from above), the target (a 4 or a 6), which was always upright from the avatar's perspective, and the distractor. The distractor was always in the diagonally opposite square to the target. On Related condition trials (50%) the distractor was the target digit rotated 180 degrees. On

Unrelated condition trials (50%) the distractor was a different digit (a 6 if the target was a 4, and vice-versa) but upright from the avatar's perspective. On half the trials the avatar shared the participant's perspective (Shared Perspective trials), and on half she was located above the grid and saw the scene upside-down (Opposite Perspective trials). Shared perspective trials were included to ensure that the egocentric response was sometimes the correct one, but together with Unrelated trials with a target 6 (bottom right image on Fig 1) did not form part of the analyses. Responding terminated the trial, or if 3500 ms had elapsed without a response the trial terminated automatically. There was then 1000 ms of blank screen prior to the next trial.

Before performing the task participants completed 16 warm-up trials, 4 each of the Shared/Related, Shared/Unrelated, Opposite/Related, and Opposite/Unrelated trial types, each further subdivided into 2 'four' cue trials and 2 'six' cue trials, with feedback. The experimental block consisted of 64 randomly-presented trials, equally divided among all trial types and grid location such that, for example, there were 32 Shared Perspective trials, 16 of which occurred with a Related distractor, 8 of which with the target cue 'six', appearing twice in each of the four grid squares.

Simon task. The Simon task also consisted of 16 practice trials (with feedback as before) followed by a block of 64 experimental trials, randomly presented and equally divided between congruent/incongruent and red/green squares. Each trial began with a fixation cross for 150ms, followed by a 350 ms blank interval and then the stimulus square for 400ms on either the left or right side of the screen. Participants were instructed to press either 3 or 9 on the top row of the keyboard according to the colour of the square (key/colour mappings counterbalanced across participants), not its position. The 6 on the top row was aligned with the centre of the screen. They were told to be as quick but also as accurate as possible. Participants could respond during the stimulus presentation and for up to 900ms of blank screen afterwards. On congruent trials, the location of the correct key corresponded to the spatial location of the square, and on incongruent trials it did not. This difference (incongruent minus congruent trials) generates the Simon Effect (Simon & Rudell, 1967), a measure of the ability to inhibit information on an irrelevant (spatial) dimension.

Results

Accuracy was high ($M = 95\%$, 95% CI [93%, 96%]). There were a total of 13 trials with no response (timeouts), which were classified as errors. None of the RT variables deviated from normality (Shapiro-Wilks tests $> .5$), but all accuracy variables did. All correct trials were included in the RT analyses (All > 259 ms).

Right Distractor Effect. Participants were on average 387 ms slower ($SE = 38$ ms) to select a target 4 from the avatar's perspective when the distractor was a match (4) from the self-perspective than when it was not (6), $t(42) = 10.11$, $p < .001$, $d = 1.542$, $BF_{10} > 1000$, one-tailed. A Wilcoxon Signed-Rank test found accuracy was also lower ($M = 89\%$ vs. 97%), $W(43) = 40$, $p = .001$, $d = .557$, one-tailed. Participants thus demonstrated a right distractor effect.

Wrong Target Effect. Participants were on average 76 ms slower ($SE = 41$ ms) to select a target 6 that looked like a 9 than an ambiguous target (an upside-down 4), $t(42) = 1.898$, $p = .032$, $d = .289$, $BF_{10} = 1.6$, one-tailed. A Wilcoxon Signed-Rank test found accuracy was also lower ($M = 85\%$ vs. 89%), $W(43) = 158.5$, $p = .039$, $d = .267$, one-tailed. Participants therefore also demonstrated a wrong target effect.

Comparison of Effects. The right distractor effect was larger than the wrong target effect, $M_{Diff} = 311$ ms, 95% CI [175, 448], $t(42) = 4.604$, $p < .001$, $d = .702$, $BF_{10} = 293$, two-tailed.

Relationship with the Simon Task. There was no evidence of a relationship between the size of the Simon Effect (Congruent RT = 393 ms; Incongruent RT = 422 ms; $t(42) = 7.063$, $p < .001$, $d = 1.077$, $M_{Diff} = 29$ ms, 95% CI [21, 38]) and either the size of the Right Distractor Effect, $r(43) = .012$, $p = .939$ or the Wrong Target Effect, $r(43) = .049$, $p = .756$.

New analyses of previous data. In order to test for the robustness of these effects we ran the same tests on the data from the original study by Samuel, Legg, et al. (2019). There are differences between the present study and these others, most notably the inclusion of trials from both 90-degree perspectives around the grid, but the fundamental contrasts indicated in Figure 1 were nevertheless present. We used one-tailed t-tests for the contrasts or one-tailed Wilcoxon signed-rank tests where

the distribution of at least one cell was not normal. There were significant wrong target effects in both experiments, Exp 1: $M_{Diff} = 115\text{ms}$, $t(30) = 2.04$, $p = .025$, $d = 0.366$, $BF_{10} = 2.3$, Exp 2a & 2b combined: $M_{Diff} = 81\text{ms}$, $W(61) = 1277$, $p = .009$, $r = .215$, and significant right distractor effects in both experiments, Exp 1: $M_{Diff} = 598\text{ms}$, $t(30) = 7.194$, $p < .001$, $d = 1.292$, $BF_{10} > 1000$, Exp 2a & 2b combined: $M_{Diff} = 561\text{ms}$, $W(61) = 1885$, $p < .001$, $r = .611$. The present experiment thus represents a third replication of the finding of independent effects of a right distractor and a wrong target, in each case with similar magnitudes and effect sizes.

Other results. We conducted a 2: Target (6 vs. 4) x 2: Distractor (Related vs. Unrelated) x 2: Perspective (Shared vs. Opposite) mixed-design ANOVA on mean RTs for correct trials (see Table 1). This was to confirm that the task conformed to the expectation that opposite perspective and related distractor trials would be harder. The analysis found the expected main effects of Perspective, $M_{Shared} = 1009\text{ ms}$, $M_{Opposite} = 1398\text{ ms}$, $F(1, 42) = 167.327$, $MSE = 62473$, $p < .001$, $\eta_p^2 = .799$ and Distractor, $M_{Related} = 1338\text{ ms}$, $M_{Unrelated} = 1028\text{ ms}$, $F(1, 42) = 237.425$, $MSE = 34825$, $p < .001$, $\eta_p^2 = .850$. There were also significant interactions between Perspective and Target, $F(1, 42) = 19.353$, $MSE = 13129$, $p < .001$, $\eta_p^2 = .315$, owing to longer response times on 6 trials from the opposite perspective, and also Perspective and Distractor, $F(1, 42) = 27.988$, $MSE = 24424$, $p < .001$, $\eta_p^2 = .400$, owing to longer RTs on related distractor trials from the opposite perspective.

Table 1. Mean response times and standard errors.

	<u>Trial Type</u>			
	<u>4</u>		<u>6</u>	
<u>Perspective</u>	<u>Related (SE)</u>	<u>Unrelated (SE)</u>	<u>Related (SE)</u>	<u>Unrelated (SE)</u>
Shared	1158 (46)	904 (37)	1081 (39)	893 (34)
Opposite	1519 (65)	1132 (53)	1595 (69)	1184 (59)

Discussion

Results from the present study showed that the presence of a right distractor and the requirement to select a wrong target both contributed independently to the difficulty of a perspective-taking task. Analyses of earlier data showed that these effects are robust, occurring twice before in previous research (Samuel, Legg, et al., 2019). Our results therefore imply a reconfiguration of our understanding of what egocentric bias actually is, because egocentricity has traditionally been defined in terms of difficulty ignoring what is correct from one's own perspective. Overall, our data suggest that this is the *larger* bias, but not the *only* bias; the test-appropriate effect size measurements ($d_s = 0.267, 0.366, r = .215, BF_{s10} = 1.6, 2.3$) indicate it is a small-to-medium effect overall, compared to a consistently powerful right distractor effect ($d_s = 1.292, 1.542, r = .611, BF_{s10} > 1000$).

How important is the wrong target problem in perspective-taking? Given the difficulty in devising stimuli to tease apart the two effects found here, it is highly likely that the quotidian, real-world conflicts of perspective require solutions to both problems simultaneously in order to generate an appropriate response. For instance, if I am asked by someone opposite me to pass an object that is on their right (my left), I need to ignore both what is on my right *and* select what is on my left to succeed. Although less intrusive, the wrong target problem is therefore likely to occur with only slightly less frequency than the right distractor problem under such conditions.

At least two important theoretical considerations follow from these findings. The first concerns the source of the wrong target effect. Some scholars support the idea that theory of mind is to some extent domain-specific (Baron-Cohen, 1995; Cohen, Sasaki, & German, 2015; Leslie, German, & Polizzi, 2005; Leslie & Thaiss, 1992), while others argue that more generalised processes are involved (Gopnik & Wellman, 1992), and that low-level alternative explanations exist for some important results in the field (Heyes, 2014a, 2014b; Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014; Santiesteban, Shah, White, Bird, & Heyes, 2015). At present it is not clear whether the wrong

effect is generated by a generalised error avoidance process¹. Future research might attempt to relate the two using an error avoidance task with no perspective-taking element. Support for a role of general error avoidance would weaken the argument for domain-specificity, or further caveat its remit. However, underpinning this hypothesis is a *further* question, namely how generalizable the wrong target effect in *perceptual* perspective-taking might be to analogous tasks involving mental states such as beliefs or desires. While the logic of the wrong target effect applies to all such cases, we have so far only demonstrated it in perceptual perspective-taking.

Secondly, and crucially, regardless of the source of the wrong target effect it should manifest only in tasks which require an outward response. This would place the wrong target effect in a later, perspective selection phase rather than an earlier perspective calculation phase (Baillargeon, Scott, & He, 2010; Qureshi & Monk, 2018). In contrast, the right distractor effect should be present for both explicit *and* implicit tasks, such as violation of expectation and anticipatory looking paradigms. In recent years the results of such tasks have reduced the age at which false belief understanding is thought to emerge from around 4 years (Wellman et al., 2001) to shortly after the first year (Onishi & Baillargeon, 2005; see also Tauzin & Gergely, 2018), and indicated that chimpanzees understand others can have false beliefs (Krupenye, Kano, Hirata, Call, & Tomasello, 2016). It has been proposed that removing the requirement to respond allows young infants, whose ability to select between perspectives is underdeveloped, to succeed (Baillargeon et al., 2010; though see Heyes, 2014a). An alternative or perhaps complementary explanation is that implicit tasks do away with the wrong target problem. In support of this possibility, in our task the requirement to select the avatar's perspective was the same whether the target was wrong or merely ambiguous, and therefore the wrong target effect demonstrates *extra* difficulty over and above perspective selection alone.

¹ Note that although there is likely to be a component of error avoidance in the Simon task it is generally considered a test of inhibitory control rather than error avoidance per se, and therefore the absence of a relationship between these tasks in our study does not (in our view) rule out this possibility.

There are caveats we should apply to our wrong target contrast. Firstly, we could only create targets that contrast in terms of their recognisability. Our reasoning here is that a 9 is ‘more wrong’ because it is identifiable as something other than the cue, but the upside-down 4 is ambiguous and is thus wrong in a more limited sense. This is not precisely the same as a target that is clearly wrong and a target that is not, but rather a proxy for such a contrast, which might be empirically impossible to create in its purest form. We therefore allow that, at its most basic, the wrong target effect shows that the right distractor effect does not hold a monopoly over difficulty in such tasks. An additional caveat is that our results are based on a single paradigm, and with numerical stimuli only. Further research would be useful in determining whether independent effects are also found in other tasks and with other stimuli. However, as we described in the introduction it is difficult to conceive of tasks and stimuli that allow each effect to be measured separately.

Finally, the results of the Simon Task showed no relationship between either effect and our measure of executive function. The relevant Pearson’s r figures ($r = .012$ and $.049$ respectively) suggests that any such effect would be too small to be of interest². This is problematic for accounts of egocentric bias as predicated at least in part upon such processes, but given the plurality of the forms of executive function and the means of measuring them (Miyake & Friedman, 2012; Miyake et al., 2000), we suggest further research is necessary before drawing firm conclusions. However, the absence of any relationship allows us to rule out the possibility that the independence of the wrong target and right distractor effects are artefacts of variable demands upon executive control.

Conclusion

The difficulty in taking perspectives that conflict with our own has usually been ascribed to the difficulty in ignoring our perception of what is correct. Overall, our results identify a right

² An a priori power test using G*Power 3.1 suggests over 3000 participants are required for an 80% probability to detect the larger of these two effect sizes ($r = .049$).

distractor problem and a wrong target problem, both of which must be solved to arrive at a correct judgment about other perspectives.

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None.

Disclosure of interest

The authors report no conflicts of interest.

Open Practices Statement

The data for the experiment can be found here: <https://osf.io/vwsfn>, and the experiment was not pre-registered.

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