Cognition 262 (2025) 106191

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Full Length Article

(Un)intentionality bias in action observation revisited

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ARTICLE INFO

Keywords:
Action observation
Intentionality bias
Intentionality attribution
Other-agency

ABSTRACT

When observing individuals in action, we often infer their goals and intentions. Yet, in situations where actions are ambiguous and could be either intentionally generated or not, there is a tendency to perceive these actions as internally driven. This intentionality bias is influenced by individual differences in schizotypal cognitive style.

In this study, we examined how healthy individuals distinguish between intentional and unintentional actions when perceiving actions of a finger attached to a pulling device. Participants reported to use different strategies to infer intentionality (e.g., action onset, perceived movement speed, hand and finger posture) and tended to attribute more intentionality to actions where the posture of the finger aligned with the final goal of the action (i.e., a bent finger pushing a button was perceived more intentional than a straight finger doing the same action). Moreover, the perceived action intentionality varied depending on the individual schizotypal cognitive style. The tendency to perceive the action as intentional when it was done with a bent finger rather than a straight finger decreased as the participants' schizotypal scores increased.

These findings suggest that intentionality attribution is not based on processes that automatically infer intentions as the primary cause of human actions. Rather than being an intentional bias, we believe that attributing and denying intentions requires the coherent integration of high- and low-level cognitive processes modulated by individual differences.

1. Introduction

Being able to infer the intentions behind other people's actions is an important part of social interaction (Roodenrys et al., 2021). When we observe people performing an action, we rarely doubt that they are not in control of their bodily movements, and we assume their behaviour is guided by an internal goal. However, in ambiguous situations we may also consider that their behaviour was not fully intentional. For example, when a person steps onto your toe we may immediately react as if they are responsible for that action. However, we may change our view if we later realise that they were pushed and that it was just an accident. This tendency to interpret an individual's action as intentional rather than accidental is called the intentionality bias (Moore & Pope, 2014; Rosset, 2008).

While we can infer the subjective states of another person (e.g., confidence) from observing their actions (Patel et al., 2012), deciding whether a person's behaviour is intentional or unintentional may require more elaborate processes. In a series of studies (Rosset, 2008), participants were given sentences that described actions that were either done on purpose (intentional) or by accident (unintentional). When participants had to make their decision under time pressure (i.e., speeded conditions), they more frequently interpreted the actions as intentional. Rosset proposed a dual-processing model in which interpreting individuals' behaviour as intentional serves as the default and rapid explanation of others' behaviour (the intentionality bias mentioned above). Conversely, recognising behaviour as unintentional necessitates a longer processing time and processing load to override this bias.

A study by Moore and Pope (2014) further explored the existence of the intentionality bias using action stimuli. Participants were shown video clips of a hand with a finger strapped to a keyboard which moved in a downwards motion, and they were told this movement could either

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https://doi.org/10.1016/j.cognition.2025.106191
Received 20 December 2024; Received in revised form 17 March 2025; Accepted 14 May 2025
Available online 20 May 2025

be intentional ("*the agent actively pressed the button*") or unintentional ("*the agent's finger was passively moved by a pulley device attached to the underside of the keyboard*"). Participants perceived the action more often as intentional rather than unintentional despite the fact that the finger was moved via the pulley device and was therefore unintentional. This finding further supports the dual-processing model (Rosset, 2008) with the idea that when we observe the actions of others, we automatically assume them to be intentional.

Attributing intentionality is also influenced by individual differences. Individuals with high schizotypy attribute more meaning to random events and to people's behaviour, showing an over-intentionality bias (Rinaldi et al., 2018). In a similar way, Moore and Pope (2014) showed a positive relationship between schizotypy and over-attributing intentionality to observed actions. That is, individuals who scored high on schizotypy traits had a stronger intentionality bias. The authors suggested that this over-attribution may be due to cognitive deficits that might characterize people with high schizotypy traits and consequently hinder their ability to infer unintentional explanations (i.e., to override automatic intentional explanations according to the dual-processing model).

However, the study of Moore and Pope (2014) used only one clip of the same actor, and the movement started at three different times after the onset of the clip (100, 400, and 700 milliseconds; see Moore et al., 2013 for details on the delays). This is potentially a problem because the more time that elapses from the start of the video to the onset of the action, the more likely it is that participants perceive the agent as having more time to act, and consequently that the action is more intentional (Caruso et al., 2016). Indeed, observing action in slow motion increases the tendency to perceive the actions as intentional (Spitz et al., 2017). Furthermore, in the Moore & Pope original study (2014), participants reported the perceived intentionality verbally without time constraints and the number of trials (24 in total) limited the possibility to explore the influence of time in the intentionality bias.

In this study we aimed to replicate the intentionality bias for ambiguous actions and to test the role of time in the perception of intentionality. We used more than one video, increased the number of time delays between clip onset and action, increased the number of trials and, instead of verbal responses participants completed the task using a keypress where speed was emphasised. We hypothesized that the time elapsed between observing a static hand and its movement will modulate the perception of intentionality.

2. Material and methods

2.1. Transparency and openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All data, analysis code, and research materials are available at https://osf.io/b4yxp/. Data were handled and analysed using R 4.0.2 (R Core Team, 2022) unless stated otherwise. The experiment's design, sample size, data processing, and data analyses were pre-registered[2] unless stated otherwise.

2.2. Participants

A total of 42 participants (female = 28, male = 13, prefer not to say = 1; Age mean ± standard deviation, range [min–max], 22.05 ± 7.41 [18–51]) took part in the study in exchange for partial course credit or monetary compensation. The task, procedure, and methodology were reviewed and approved by the institutional review boards of the University of Hull (protocol number FHS466) and carried out in accordance with the standards set by the Declaration of Helsinki. All participants were naïve to the task and purpose of the experiment. Informed consent was obtained before starting the task.

2.3. Apparatus and task

2.3.1. Materials

We recorded at 240 frames per second a male and a female model with their right index finger strapped over a button. To create clips where the finger lowered until the button touched the box, a metal stick connected the button to a black box and was manually controlled by the experimenter (Corresponding Author). During the recording, the experimenter and the models synchronized their movements to ensure a smooth transition of the finger.

The experimenter (Corresponding Author) edited and down sampled the original clips to create four 30 frames per second clips lasting 5 s each using the following procedure. The clip started with the index finger strapped over a button. This was created by making the frame before the start of the movement last for 3 s. Then, the movement started, showing the finger and button lowering until the button touched the box. The movement duration at 30 frames per second lasted on average around 9 ± 1.155 frames (corresponding to a movement duration of ~300 ms). The last part of the clip showed the last frame of the action until 5 s were reached. Finally, the experimenter added grain noise to increase the perception of a live recording so that the duplication of the frames before (after) movement onset (stop) was unnoticed and the clip did not look manipulated (clips can be found on OSF). In all four clips there is no clear muscle contraction of the model's hand or tendon stretch of the finger. In all four clips, a lowering of the dorsum skin can be observed.

Finally, we took the first frame of each clip and created 90 scrambled images from it using a custom Matlab script (Mathworks Inc., see Procedure section).

2.3.2. Procedure

Participants taking part in the study read an information sheet and signed informed consent before beginning the study. Then, as a cover story, we told participants that we had developed a device able to pull a finger if attached to a button. Participants were shown a prototype device and shown the internal electrical circuit from a side opening to reinforce the credibility of the cover story. Then, we told participants that they were going to observe clips of people with the right index attached to the button and that in some cases the device pulled the finger of the person, or the person pushed the button. They were then told that their task was to guess at their best when the observed action (the index moving downwards) was either intentional (the person pushed the button on their own volition) or unintentional (the person's finger was pulled). After the instructions, participants completed a practice and an experimental session.

Each trial was composed of a Fixation cross (random duration between 1 s and 1.250 s; see Fig. 1), followed by the presentation of scrambled images that anticipated the presentation of the model with the finger attached to the device. Since we manipulated the movement onset of the action, we reasoned that trials with a short action onset (e.g., 0.1 s) would be too brief for participants to focus properly, thereby increasing the risk of stereotyped responses. Hence, the duration of the scrambled images was matched to the action onset so that action onset always happened 3 s after the fixation cross disappeared. In other words, for each movement onset (in seconds: 0.100; 0.400; 0.700; 1.066; 1.666; 2.500 after the model was visible) the duration of the scrambled images was manipulated accordingly (2.900, 2.600, 2.300, 1.933, 1.333, 0.5 s). After the movement ended (~3.300 s after the fixation cross), the frames of the clips presenting the last frame of the action remained on screen until 3.666 s after the fixation cross (110 frames at 30fps). After that, a question appeared on the screen (Intentional vs Unintentional) and participants were asked to indicate if the action was intentional or unintentional using the "a" and "s" keys with their left had (key mapping,

[2] The AsPredicted file mentions the authors in the text. We uploaded the original PDF file with the authors' names removed.

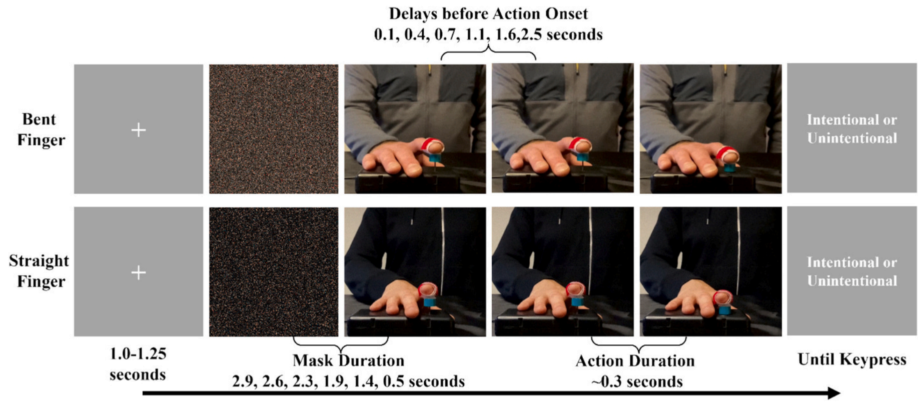

Fig. 1. Depiction of the trial timeline. Mask duration is reversed to Match the Delay duration as the sum of Mask and Delay duration always equals 3 s.

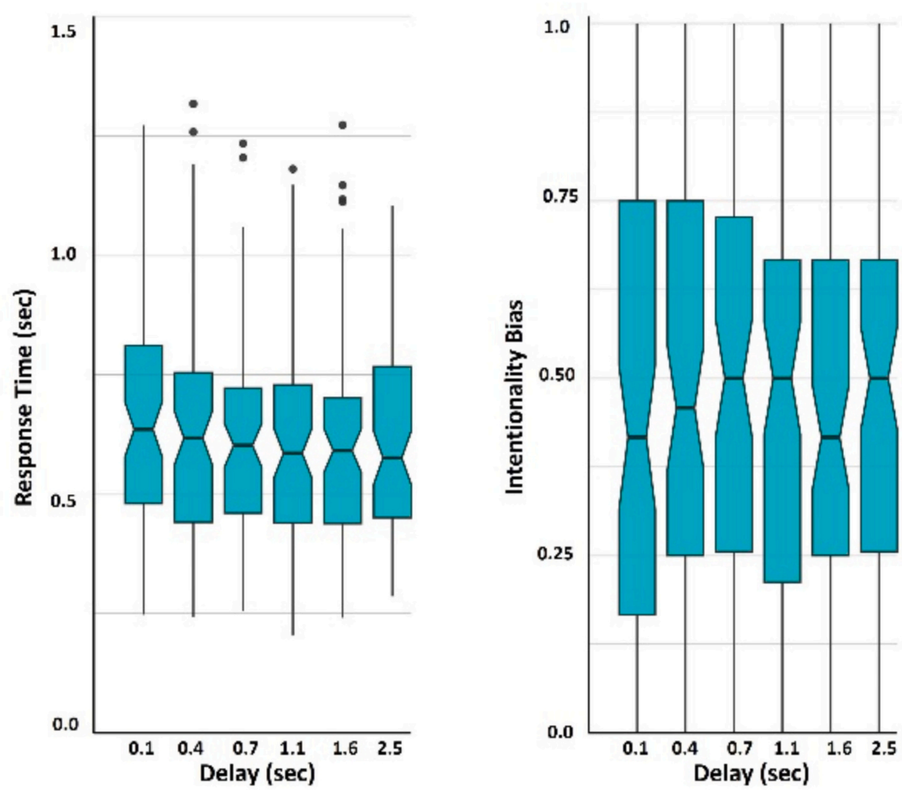

Fig. 2. RT and ratio of Intentional Responses. For each experimental condition we visualised the median boxplots (with lower and upper hinges corresponding to the 25th and 75th percentile and whiskers extending no further than 1.5 * "Interquartile Range" from the hinge). The notched boxplot gives a roughly 95 % confidence interval for comparing medians. If the notches of two boxes do not overlap, this suggests that the medians are significantly different.

a/s for intentional/unintentional with text "Intentional or Unintentional", a/s for unintentional/intentional with text "Unintentional or Intentional", see Fig. 1, was counterbalanced across participants).

Importantly, to ensure participants were paying attention to the hand area, an asterisk may have appeared for 0.2 s overlaying the image around the finger area at a randomly chosen time between 2.9 and 3.233 s after the fixation cross (see Supplementary Fig. S1), that is 0.100 before or 0.233 after action onset. These additional attention check trials (16 in total) were randomly presented during the task and the intentionality responses and reaction times were removed from the main analyses.

Participants were prompted to verbally report to the experimenter when they saw the asterisk appearing so that the experimenter could annotate the detected asterisks (i.e., that the participant detected the catch trial). Participants were also made aware of reporting the asterisk during the practice trials so that the experimenter could check if any part of the instruction was not clear.

After the completion of the task, participants were asked to complete a four-part questionnaire. First, we asked participants the following: "*Is there something you would like to say about the study? Some considerations, doubts, or questions you may have or have had while completing it?*". The scope of this question was to assess whether participants would spontaneously and explicitly report without any prompt that they did not believe the instructions. Then, we asked them about any strategy they may have used with the following question: "*What criteria/strategy have you used to discriminate between intentional and unintentional actions?*". After annotating their answers, we asked participants to rate how much they agreed (0, not at all, 10 very much) with the following four questions: "*That some actions were intentional and some unintentional*", "*That the device in the clips was working*", "*That the snow flake* (*i.e., asterisk*) *could* *affect your judgement*", "*That the snow flake was used to distract you*". The first two questions were used to assess how much participants believed our cover story, the latter questions were used to avoid participants guessing the scope of the study and realise the small deception in the cover story. These four questions were presented on a single excel file sheet and the experimenter randomised the presentation order for each participant.

After this, participants completed the Cardiff Anomalous Perceptions Scale (CAPS; Bell et al., 2005, Bell et al., 2011), a 32-item self-report measure designed to assess perceptual anomalies that includes subscales evaluating the distress, intrusiveness, and frequency of these experiences. During CAPS completion, the experimenter left the room to allow the participant some privacy and came back in once the participant had indicated it was completed. Participant then provided some demographic information (age and gender).

Finally, participants read the debrief form. The experimenter explained that the device was not actually working and how the videos were created. After that, the experimenter asked if we could keep the data. No participants verbally declined their initial consent.

2.4. Measures, data processing and statistical approach

We collected the reaction times and the responses participants provided when indicating if the observed action was (un)intentional, and computed the CAPS scores. Note that we did not allow participants to answer during the whole clip and reaction times started from the moment the question appeared (3.666 s after the fixation cross, that is, around 0.366 s after the button and the finger stopped moving). For this reason, we did not remove answers with RTs inferior to 0.150 s as anticipatory answers (different from what we pre-registered).

Following our pre-registration, we excluded trials with slow answers (RT $>$ 3 s; 1.01 %). Then, we excluded trials with RT exceeding 3SD of the average RT within each experimental block (1.25 %). We plotted the whole RT dataset and visually checked RT's distribution showing a typical RT skewed distribution. We removed one participant with overall RT exceeding 3SD from the remaining sample average. Visual inspection of the data also showed that three participants answered stereotypically depending on the observed model (i.e., participants did not vary their answers, always answering "yes" or "no"). That is, they interpreted the action always as intentional for one model (intentional action $>$98.52 %) but not to the other (intentional action $<$1.41 %). Participants believed our cover story (i.e., that the device was working, average rating of 7.04 $\pm$ 2.47 standard deviation, and that there were both intentional and unintentional actions, 7.38 $\pm$ 2.29). No participants rated our belief deception questions on average 2SD below the sample average. So, we did not remove further participants. The final sample consisted of 41 participants. This sample and exclusion criteria (keeping RTs $<$ 3.0 s and removing participants with an average rating 2SD inferior of the final sample) were also used for all non-pre-registered analyses.

Note that in our pre-registration we mentioned the possibility to remove trials with RTs $<$ 1.5 s and to exclude participants who rated on average below 5 the belief deception questions. Reanalyses of the dataset using a combination of different criteria (RTs $<$ 3.0 s and average rating $<$ 5, RTs $<$ 1.5 s and average rating $<$ 2SD, RTs $<$ 1.5 s and average rating $<$ 5) lead to the same results and conclusions reported in the main text. Moreover, re-analyses excluding participants who responded in a stereotypical way, or removing the participant whose catch trial accuracy got lost (the asterisk appearing on the video; see results sections) lead to the same conclusions (these re-analyses are available on OSF).

To perform the pre-registered correlational analyses to assess for individual differences, we defined the total and subscales CAPS scores as in the original papers (Bell et al., 2005, 2011). Total CAPS score was calculated by counting the number of endorsed items. Each subscale CAPS score was calculated by summing the ratings (ranging from 1 to 5) for all endorsed items belonging to that subscale. Therefore, the possible range for the total CAPS score was 0 (low) to 32 (high), and for each of three dimensions (distress, intrusiveness, and frequency) the possible range was 32 to 160. Unfortunately, due to a technical error, we missed the ratings of one CAPS item for half of the sample. Hence, we computed the total CAPS score and each subscale CAPS score on 31 items (total CAPS score range 0–31, subscale CAPS score range 31–155) for all participants.

We used the afex (v1.4-1; Singmann et al., 2024) and lme4 packages (v1.1.27.1; Bates et al., 2015) to perform Linear Mixed Models (LMM) with fixed effects and complex random intercepts (CRIs) as scalar random effects (Scandola & Tidoni, 2024) on response type (intentional, unintentional) and reaction times (see each result section for the fixed effects used in each analyses). We report ANOVA-like tables with *p*-values computed on the estimates of the simplified LMM (Scandola & Tidoni, 2024). For all LMM models, we computed the conditional R2 (performance v0.7.3, Lüdecke et al., 2021). For LMMs on RT, we also report the partial eta-squared as a measure of effect size (effectsize v0.4.5; Ben-Shachar et al., 2020). For each multiple comparison, we report the β estimate and the individual Holm corrected p-value computed from the final LMM using emmeans (v1.6.2-1; Lenth, 2025).

Statistics were performed using R 4.0.2 (R Core Team, 2022) on ARC4, part of the High Performance Computing facilities at the University of Leeds.

3. Results of pre-registered analyses

We lost the accuracy of catch trials for one participant. Removing this participant from the sample does not change the results of the pre-registered analyses (see the "Catch" file on OSF). Overall, participants paid attention to the area where the finger moved (asterisk detection, mean $\pm$ standard deviation, 15.66 $\pm$ 0.76).

3.1. The effect of delay in the attribution of intentionality

We first performed an ANOVA on response type and RT with Delay (D1 = 0.1 s; D2 = 0.4 s; D3 = 0.7 s; D4 = 1.1 s; D5 = 1.6 s; D6 = 2.5 s) as a single within-subject factor.

3.1.1. Reaction times

We observed a tendency of Delay, $F(5, 197.66) = 2.22$, $p = 0.054$, $\eta p^2 = 0.053$, with RTs at D1 (0.657 $\pm$ 0.223 s) to be slower than D5 (0.606 $\pm$ 0.209 s; $\beta = 0.051$, $p = 0.060$).

3.1.2. Response type

The results revealed no main effect of Delay, $\chi^2(5) = 5.46$, $p = 0.362$.

3.2. The effect of posture and delay in the attribution of intentionality

We explored whether the perception of intentionality was affected by the posture of the finger by performing an ANOVA on response type and RT with Delay and Posture (straight and bent finger) within-subject factors (Fig. 3).

3.2.1. Reaction times

We observed a tendency of Delay, $F(5, 197.69) = 2.22$, $p = 0.054$, $\eta p^2 = 0.053$, a main effect of Posture, $F(1, 39.32) = 10.36$, $p = 0.003$, $\eta p^2 = 0.208$, with slower RTs for actions performed with the bent (0.640 $\pm$ 0.209 s) compared to the straight finger (0.601 $\pm$ 0.199 s). The Delay by Posture interaction was not significant, $F(5, 5485.35) = 0.99$, $p = 0.419$, $\eta p^2 = 0.001$.

3.2.2. Response type

The analysis revealed no main effect of Delay, $\chi^2(5) = 4.91$, $p = 0.427$, a main effect of Posture, $\chi^2(1) = 54.89$, $p < 0.001$, and a Posture by Delay Interaction, $\chi^2(5) = 15.10$, $p = 0.010$. Specifically, actions of

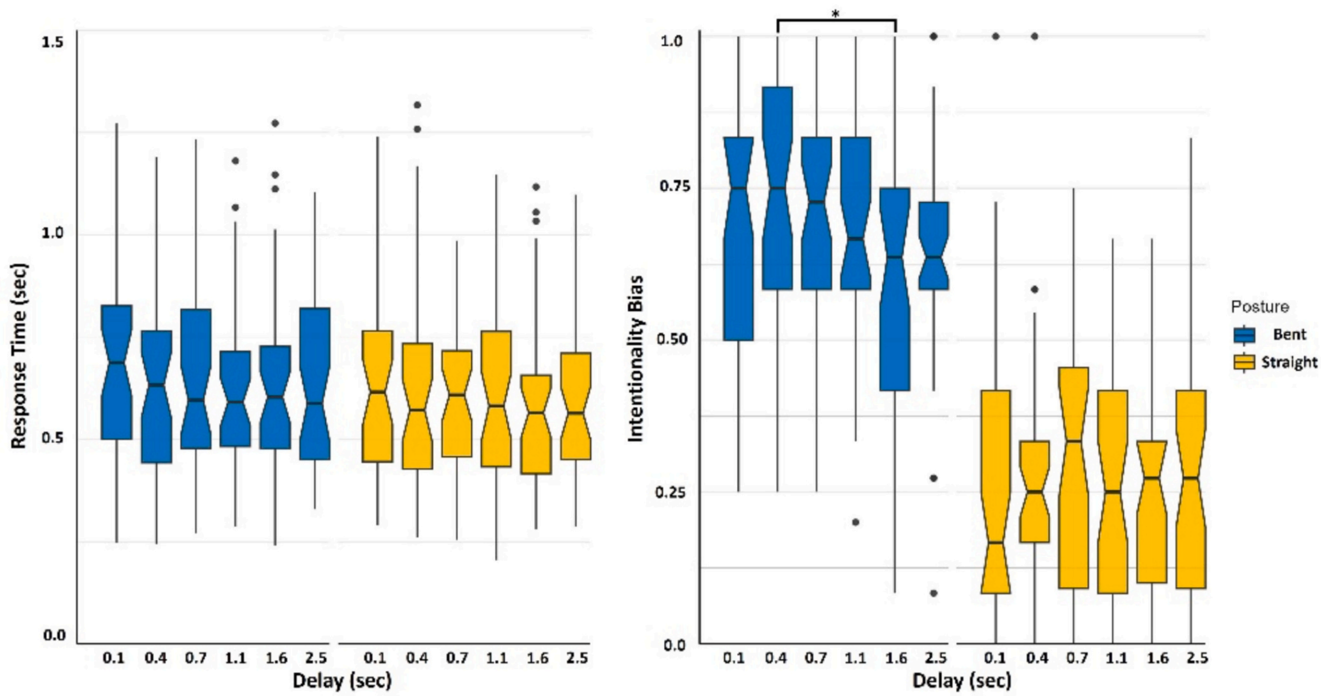

Fig. 3. RT and ratio of Intentional Responses for each experimental condition separated for the bent and straight finger. See description of Fig. 2 for details on the visualised boxplots.

the bent finger were always perceived as more intentional (all $|\beta| > 1.790$, all $p < 0.001$). Moreover, while Delay did not modulate the attribution of intentionality to the actions performed with the straight finger (all $|\beta| < 0.279$, all $p = 1.000$), the attribution of intentionality to the actions performed with the bent finger was lower at D5 (0.599 ± 0.279) compared to D2 (0.718 ± 0.216; $\beta = -0.616$, $p = 0.017$).

3.3. *Does the attribution of intentionality change over time?*

We explored whether the perception of intentionality changed between the first and second half of the study for the two postures by performing an ANOVA on RT and response type with Blocks and Posture as within-subject factors.

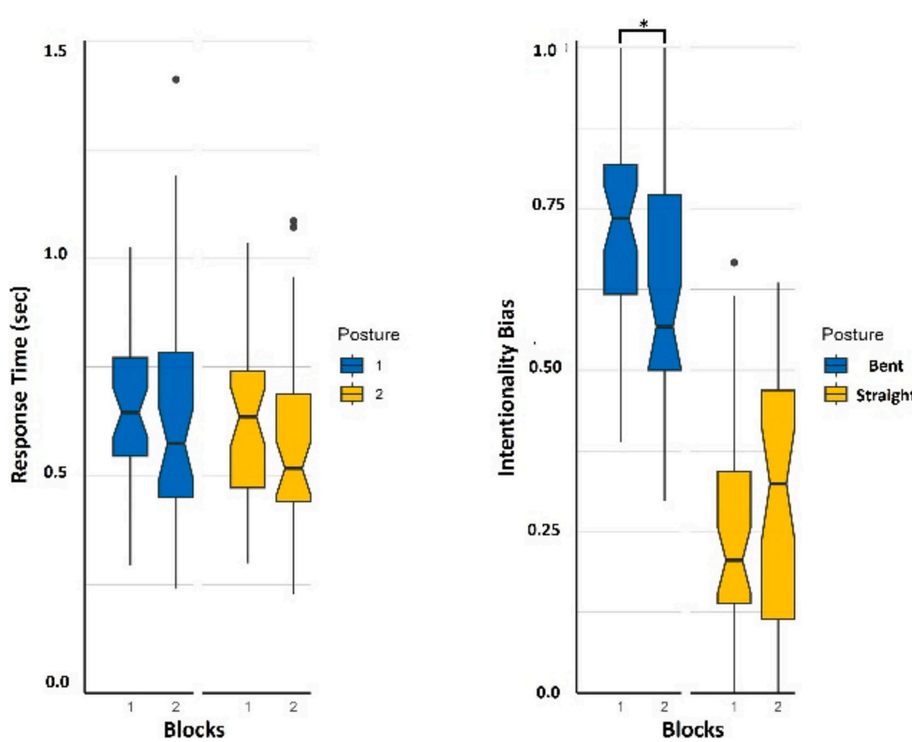

Fig. 4. RT and ratio of Intentional Responses for each block separated for the bent and straight finger. See description of Fig. 2 for details on the visualised boxplots.

3.3.1. Reaction times

We observed no effect of Blocks, $F(1, 39.95) = 2.64$, $p = 0.112$, $\eta p^2 = 0.062$, a main effect of Posture, $F(1, 39.18) = 9.77$, $p = 0.003$, $\eta p^2 = 0.199$, as reported above. The Block by Posture interaction was not significant, $F(1, 39.50) = 2.80$, $p = 0.102$, $\eta p^2 = 0.066$.

3.3.2. Response type

The analysis revealed no main effect of Blocks, $\chi^2(1) = 2.41$, $p = 0.120$, a main effect of Posture, $\chi^2(1) = 55.63$, $p < 0.001$, and a Blocks by Posture interaction, $\chi^2(1) = 10.11$, $p = 0.001$. Specifically, actions of the bent finger were always perceived as more intentional (all $|\beta| > 1.867$, all $p < 0.001$). Moreover, while the attribution of intentionality did not change for the actions performed with the straight finger between blocks (Block1, 0.252 ± 0.179; Block2; 0.286 ± 0.201; $\beta = -0.162$, $p = 0.209$), participants decreased the attribution of intentionality from Block 1 (0.716 ± 0.159) to Block 2 (0.626 ± 0.197; $\beta = 0.443$, $p < 0.001$) for the actions performed with the bent finger (Fig. 4).

3.4. Is the attribution of intentionality related to schizotypy?

We explored whether the tendency to perceive an action as intentional correlates with individual total CAPS scores. However, to perform pre-registered correlational analyses, we had to remove one subject as they did not answer three questions of the CAPS. Hence, correlational analyses were run on 40 participants.

The total CAPS score did not correlate with the overall tendency to attribute intentionality to the observed action (i.e., with the two postures aggregated; $r = -0.044$, uncorrected $p = 0.789$). However, we found a negative and a positive correlation between the total CAPS score and the attribution of intentionality to the action performed with the bent ($r = -0.450$, uncorrected $p = 0.001$) and straight finger respectively ($r = 0.430$, uncorrected $p = 0.006$). To further explore the results of this correlation, we computed a new LMM with schizotypal traits as covariate (see Supplementary Analyses, A1).

We also ran separate correlation analyses for each posture between each CAPS dimension and the tendency to attribute intentionality to the observed action. We observed a negative and a positive correlation between the score of each CAPS dimension and the attribution of intentionality to the action performed with the bent (all $r > -0.429$, all uncorrected $p < 0.006$) and straight finger respectively (all $r > 0.414$, all uncorrected $p < 0.008$).

No correlations were found between overall reaction times or reaction times to each posture and total or subscale CAPS score (all uncorrected $p > 0.10$, all $r < 0.25$) (Fig. 5).

3.5. Non-pre-registered analyses

Rosset (2008) reported that under time pressure (i.e., speeded conditions), participants more frequently interpreted the actions as intentional. We performed an ANOVA on Reaction Times with Delay, Posture, and the Response Type (Intentional, Unintentional) as within-subjects factors. We observed a Posture by Response Type interaction, $F(1, 76.54) = 27.55$, $p < 0.001$, $\eta p^2 = 0.265$. Participants were faster in attributing intentionality (0.622 ± 0.202 s) compared to unintentionality to the bent finger (0.701 ± 0.237 s; $\beta = 0.070$, $p = 0.004$), and slower in attributing intentionality (0.715 ± 0.284 s) compared to unintentionality to the straight finger (0.587 ± 0.199 s; $\beta = 0.088$, $p < 0.001$). Moreover, participants were slower when not attributing intentionality to the bent finger compared to the straight finger ($\beta = 0.105$, $p < 0.001$), and faster when attributing intentionality to the bent finger compared to the straight finger ($\beta = 0.052$, $p = 0.017$). No other main effects or interaction were significant (all $p > 0.076$) (Fig. 6).

So far, our results suggest that the posture of the models had a strong impact on the perception of intentionality. At the end of the task, participants answered a series of questions investigating the strategies they used to complete the task. We categorized their answers based on whether they explicitly mentioned the posture of the models as a cue to infer their intentionality (see Supplementary Table S1). This way, we divided the sample into two groups and performed an ANOVA on RT and response type with Delay and Posture as within-subjects factors and Strategy (explicit or implicit mention of the posture) as a between-subjects factor (Fig. 7).

3.5.1. Reaction times

We observed no main effect of interaction of Strategy, all $F < 3.54$, all $p > 0.068$, all $\eta p^2 < 0.085$.

3.5.2. Response type

The analysis revealed a Strategy by Posture interaction, $\chi^2(1) = 12.90$, $p < 0.001$. Specifically, actions of the bent finger were perceived as more intentional by participants who mentioned the use of posture as a strategy (0.737 ± 0.192) compared to participants who did not mention it (0.614 ± 0.115; $\beta = 0.877$, $p = 0.016$), and actions of the straight finger were perceived as more intentional by participants not mentioning the use of posture as a strategy (0.317 ± 0.156) compared to participants who did (0.215 ± 0.175; $\beta = 0.831$, $p = 0.016$). No surprisingly, all participants across groups attributed more intentionality to the actions performed with the bent compared to the straight finger (all $\beta > 1.409$, all $p < 0.001$).

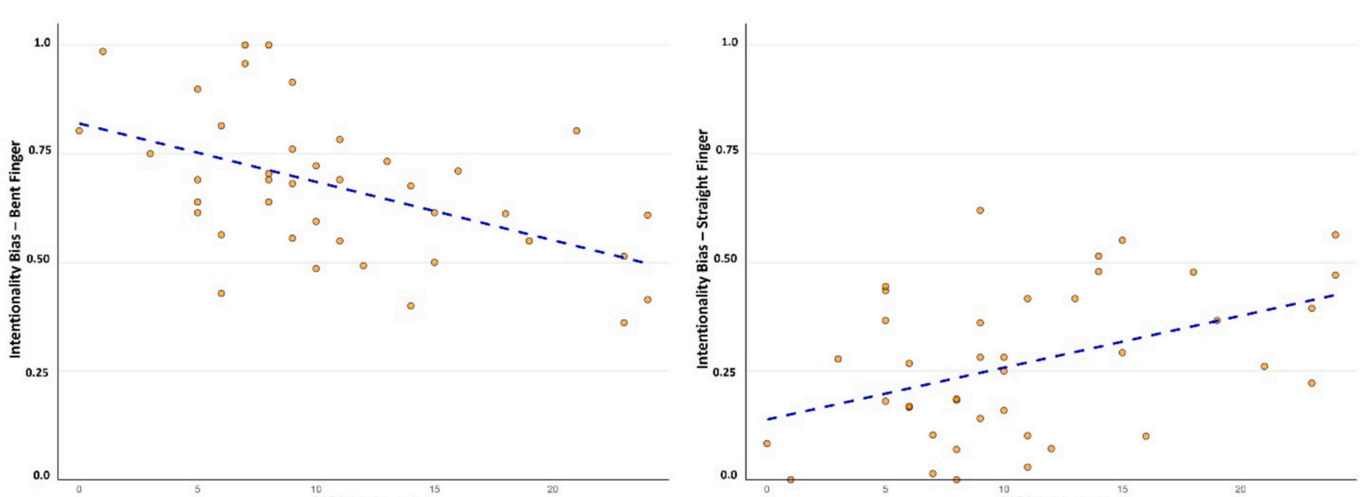

Fig. 5. Correlation between the total CAPS and the ratio of Intentional Responses separated for the bent and straight finger.

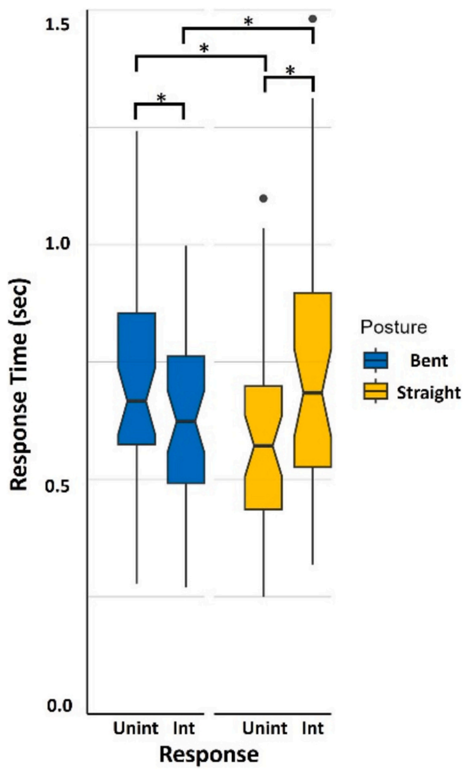

Fig. 6. Reaction Times for Intentional and Unintentional responses separated for the bent and straight finger. See description of Fig. 2 for details on the visualised boxplots.

4. Discussion

It has been suggested that people tend to interpret ambiguous human actions as intentional (Rosset, 2008; Moore and Pope, 2014; but see Monroe et al., 2015).

We investigated whether the intentionality bias could be influenced by factors other than the ambiguity of the action itself. We manipulated the time interval between the appearance of a finger attached to a device on screen and the initiation of the action. Participants were informed that the device could pull the finger down, and their task was to determine whether the person was pushing a button or their finger was being pulled by the device.

We observed participants using a variety of strategies (e.g., the plausibility of the actors' postures and temporal delay) as a criterion to distinguish between intentional and unintentional actions. Crucially, the longer an action with a plausible posture took to initiate, the less intentional it appeared. There was no modulation of the temporal delays for actions with a less plausible posture. This suggests that temporal information does not always increase the perceived intentionality of an action (Caruso et al., 2016; Hüttner et al., 2022).

Similar to a previous study (Hughes et al., 2011), RT results seem to contradict the idea that intentionality bias is automatic (Rosset, 2008). Indeed, we observed faster RTs for intentional and unintentional answers for actions with the plausible and implausible posture respectively. This suggests that the congruency between the observed posture with the final goal drives the RT advantage, rather than an automatic tendency to perceive actions as intentional by default. In addition, we also found that participants with higher schizotypy traits were more likely to attribute intentionality to actions with an implausible posture, and less likely to attribute intentionality to actions with a plausible posture.

As a whole, our findings extend the list of potential low-level cues to both time and posture that may affect the perception of intentional

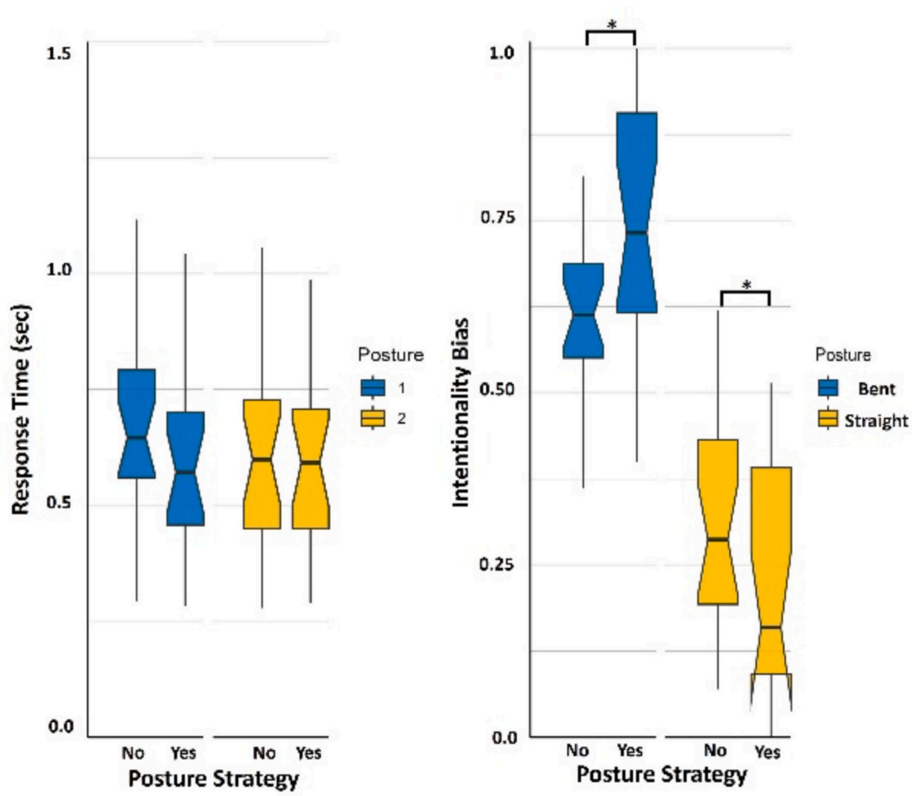

Fig. 7. Comparisons of RT and ratio of Intentional Responses for the bent and straight finger between participants who reported to use posture as a strategy to discriminate intentional and unintentional actions. See description of Fig. 2 for details on the visualised boxplots.

behaviour (Monroe et al., 2015) and further highlight the relevance individual differences have when interpreting others' actions.

4.1. Attributing intentions from action observation

Neurocognitive models of agency attribution when executing a motor action and when perceiving others' motor behaviour suggests that there is not a unique brain area devoted to the attribution of intentionality to oneself or to others (Isoda, 2016; Moore et al., 2013).

Current models of action observation suggest that the visual analysis of a body posture and its motion allows an observer to infer other's intentional mental states (Giese & Poggio, 2003; Tidoni & Candidi, 2016; Catmur, 2015; Grafton & Tipper, 2011). In our study, the action goal was always the same (i.e., pressing a button). Based on participants' verbal reports about the strategy they used, the inferred congruence of the posture with the known action goal may have received more weight in deciding whether the action was intentional. In other words, if I know you are moving to accomplish a specific goal, I expect you to have a certain body posture.

It is worth noting that in the majority of action observation studies, the acting agent rarely moves with constraints. This means that in most action observation studies there is no visual information that may cast doubt on the underlying intentionality of the agent: a person sees a freely moving individual without any constraints (e.g., strings attached), hence their behaviour is internally generated.

Two studies investigated the neural correlates of observing actions generated by a passively moved finger. Oberman et al. (2007) showed participants a hand being moved by a string while recording changes in the mu rhythm during action observation. They observed a reduced mu rhythm both when participants observed a hand moving volitionally (no strings attached) and non-volitionally (moved by strings). The authors suggested that volition is not a necessary property for activation of the action observation network during the observation of human actions. In contrast, Liepelt et al. (2008) used action stimuli where participants observed a passive movement in which a finger moved without the actor's intention (i.e., being passively lifted by a mechanical device). They observed a reduction within the inferior frontal gyrus (part of the action observation network) only in this passive condition compared to when participants observed the agent lifting the finger normally. This finding was interpreted as evidence supporting the involvement of the action observation network in automatically attributing intentions to an observed movement.

While these seminal studies are important to understand the neurocognitive mechanisms supporting action observation, visual cues might still have hinted at the underlying intentionality of the action. For example, observing the stretching of a tendon clearly suggests an internal causation of the observed movement, therefore, the action may "automatically" be perceived as intentional or as a willed attempt to move. However, the authors did not assess whether participants perceived those actions as intentional or not. In our task, none of those visual cues suggested which action was intentional and which was not (expect for posture as reported by participants). Therefore, in previous studies, visual information may have provided to the observer cues to infer who or what was causing the observed movement (if the finger was contracted, it was willed; if not, it was the machine).

Therefore, we think it likely that past studies were not ambiguous enough and therefore reported participants' ability to infer other's intentionality when visual cues alone could have been used to distinguish between intentional and unintentional behaviour. In our study those cues were not available (skin or tendon stretch was not visible so no visual cues suggested the cause of the movement) allowing participants to rely on their assumptions about what the intentional action should look like (participants knew what that the agent was going to perform; i.e., pushing the button) within an ambiguous context (i.e., agents were always attached to the device).

Crucially, for our participants, the ambiguity of the action was not related to the finger being attached to the device. Instead, the fact that time and posture modulated the perception of intentionality raises questions about the perception of human intentions. Is the perception of others' intentions merely the perception of a congruency between the posture and the goal that the posture subtends? If this is correct then, action goals achieved with a known or familiar posture and gesture may be considered more intentionally guided irrespective of contextual ambiguity. Contrary, actions performed with less familiar or more unpredictable movements (e.g., not happening within an expected time, using peculiar kinematics) may be considered less intentionally guided.

Nevertheless, if inferring intentions is nothing more than the congruency between a posture, a known action goal, and other cues (e.g., temporal), then we are left to question if there is something special in perceiving human intentions (see Potential Implications section) and whether the motor system and the action observation network (Tremblay et al., 2004; Halje et al., 2015; Mukamel et al., 2010) may predict the perceived intentionality of an agent.

4.2. Attribution of intentionality and schizotypy traits

The tendency to attribute intentionality varies among individuals (Slavny and Moore, 2017; Riekki et al., 2014). Current research suggests that individuals with schizophrenia exhibit atypical neural activation in brain regions associated with mentalizing when interpreting others' mental states (Backasch et al., 2013; Green et al., 2015; Hudson et al., 2023; Madeira et al., 2021). For example, consistent with other studies (Fuchs et al., 2024; Walter et al., 2009), Ciaramidaro et al. (2014) found overactivations within the mentalizing network when observing non-intentional behaviour, such as a gust of wind blowing a ball and causing it to knock over and break a glass of water.

While we did not test participants with a diagnosis of schizophrenia, we found that participants with higher schizotypal traits attributed less intentionality to actions performed with a plausible posture and more intentionality to actions performed with an implausible posture. A tentative explanation is that when observing familiar actions, where the body is in a familiar posture, individuals with higher schizotypal traits may exhibit less activation of the mentalizing network. Conversely, when observing actions performed in a less familiar, implausible, or visually ambiguous posture, they may tend to over-recruit mentalizing brain regions and perceive the behaviour as more intentional. This aligns with the concept of an altered mentalizing network, where hypo- and hyper-mentalizing vary depending on the ambiguity of the stimulus presented. For example, recent studies using point light action clips and video stimuli showing a human performing gestures suggested that patients with schizophrenia tend to mistakenly label actions and behaviours as having more intention than they actually have, and to consider others' gestures in ambiguous scenarios as more self-referential (White et al., 2015; Okruszek et al., 2015).

Is it possible that people with high CAPS scores attribute more agency to the device rather than removing intentionality from the actor? Unfortunately, we cannot provide an answer to this question as the agent and the device were "linked" together, and not studied in isolation. However, the fact that we observed opposite correlations depending on the type of posture may suggest that people with high CAPS scores did not flexibly integrate the observed posture with the goal of the action rather than being less able to make unintentional explanations (as suggested in Moore & Pope, 2014).

Finally, the fact that reaction times did not correlate with CAPS scores and that RTs were faster depending on the posture observed suggests that RTs might not be a good proxy for investigating the automaticity of intentionality attribution (contrary to what suggested in Rosset, 2008).

Overall, our findings are consistent with current view that people with high schizotypal traits and schizophrenic patients may have an impaired ability to process biological motion and infer others' mental states (Green et al., 2015; Martínez et al., 2024). Additionally, the tendency to hyper- or hypo-attribute intentions to others may be modulated by the familiarity or naturalness of the observed action.

4.3. Potential implications from the current study

Current mentalizing models from action observation do not question the intentionality of an acting human agent (however, see Isoda, 2016), and instead focus on the mechanisms responsible to discriminate different types of intentions. The Model of Apparent Mental Causation (Wegner & Wheatley, 1999) and its integration in a recent model of Other-Agency attribution (Isoda, 2016) suggest that, in the absence of an external causal explanation (i.e., the principle of Exclusivity), there is no reason to doubt the intentionality of our own and others' actions. Our study suggests that in ambiguous scenarios, where a human movement may have been generated by an external device, the bodily posture of the observed agent and the time it takes to start to act affect the perceived intentionality of the action. Posture and action onset may therefore be relevant for developing more human-like devices such as exoskeletons and prostheses. However, in a futuristic scenario where robotic devices are seamlessly interfaced with the human body, this presents the dilemma of whether observing a perfectly familiar action performed by a prosthetic hand will reflect the actual intention of the agent or the mechanical agency of the device.

Our study posits a fundamental question about the perception of intentionality from action observation. Is understanding intentions just making sense of what we see (Heider & Simmel, 1944), like creating a coherent "script" (Taylor et al., 2023) of the perceptual experience? The findings we report suggest that reconstructing others' intentionality depends on whether the observed body posture aligns with a potential goal and whether the body moves at the right time; in such cases, the action is likely to be perceived as intentional even if an external device may be the actual cause. In other words, if the observed action matches our expectations and follows a familiar "script", then the observer may (erroneously) have no doubts about who is in control of the moving body. Even more problematic is the scenario where an intentional act may not be perceived as intentional if it is performed with an unusual posture, such as when using an exoskeleton that cannot fully mimic humanlike postures and movements. Therefore, it is not implausible to speculate that the human ability to see others' actions as internally generated in ambiguous situations is limited and relies on our expectations and lived experience. Indeed, we rarely interact with agents whose behaviour can be labelled as not internally generated (e.g., we never interact with people moved by strings). In other words, as we would expect a rock not to move on its own, we are not surprised (i.e., we expect) to see a human body self-propel.

So, contrary to the suggestion that the intentionality bias automatically and implicitly leads us to consider all actions as intentional by default, we propose that it is the perceptual analysis of body posture and action that leads to the ascription of either intentional or unintentional behaviour.

5. Conclusion

During daily social interactions we do not doubt people are acting intentionally. However, it has also been suggested that we automatically attribute intentions even in ambiguous situations.

We expanded the current literature on intention attribution during action observation by testing how inaction duration before movement onset affects the attribution of intentionality. Our data suggest that, under ambiguous circumstances, factors like the agent's posture and the time it takes for an action to start may increase or decrease the intentionality attributed to an agent. Rather than being an intentional bias, attributing intentions appears to be a coherent integration of high- and low-level cognitive processes modulated by individual differences.

OSF link

https://osf.io/b4yxp/

CRediT authorship contribution statement

Emmanuele Tidoni: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Avena Merritt:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Elizabeth Adeyemi:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Michele Scandola:** Writing – review & editing, Visualization, Formal analysis. **Jeremy Tree:** Writing – review & editing, Visualization, Formal analysis. **Kevin Riggs:** Writing – review & editing, Conceptualization. **David George:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the corresponding author used Copilot to improve language and readability. After using this tool/service, all authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Acknowledgements

We thank Daniel Revell for his help in data collection and in the initial setting up of the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2025.106191.

Data availability

All data are available on OSF.

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