Top-Down Modulation of Motor Priming by Belief About Animacy:

A Registered Replication Report

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Stage 1 Accepted Registered Report at Experimental Psychology

Abstract

Research has shown that people automatically imitate others and that this tendency is stronger when the other person is a human compared with a non-human agent. However, a controversial question is whether automatic imitation is also modulated by whether people *believe* the other person is a human. Although early research supported this hypothesis, not all studies reached the same conclusion and a recent meta-analysis found that there is currently neither evidence in favor nor against an influence of animacy beliefs on automatic imitation. One of the most prominent studies supporting such an influence is the study by Liepelt & Brass (2010), who found that automatic imitation was stronger when participants believed an ambiguous, gloved hand to be human, as opposed to wooden. In this registered report, including both original authors, we provide a high-powered replication of this study. By doing so, the current report contributes to answering the longstanding question of whether automatic imitation can be modulated by high-level social beliefs.

How do we process other people's actions? According to decades of research, observed actions activate not only visual but also motor areas of the brain (Caspers et al., 2010), suggesting that they are processed at least in part through motor simulation (Rizzolatti & Sinigaglia, 2010). Behaviorally, motor simulation can be studied using automatic imitation: the phenomenon that task-related responses are facilitated by congruent and impeded by incongruent task-irrelevant observed actions (Cracco et al., 2018; Heyes, 2011). For instance, Brass et al. (2000) asked participants to respond to the number '1' or '2' by lifting, respectively, their index or middle finger while, at the same time, a hand on the screen also lifted its index or middle finger. The results revealed that responses were faster and more accurate when the observed action was the same as the instructed action (i.e., congruent trials) than when it was not (i.e., incongruent trials). This congruency effect has since been identified as a reliable (Genschow, Van Den Bossche, et al., 2017) and valid (Cracco & Brass, 2019) measure of automatic imitation (Cracco et al., 2018; Heyes, 2011).

While several theories exist, automatic imitation is often thought to be a consequence of sensorimotor learning (Brass & Heyes, 2005). That is, based on the fact that we typically see our own actions, it is argued that, over time, bidirectional associations emerge between the motor command producing an action and its visual image. As a result, an automatic imitative response is triggered whenever that action is observed (Brass & Muhle-Karbe, 2014; Cook et al., 2014). Stated differently, learning theories propose that automatic imitation develops primarily through self-observation. Therefore, a key prediction of these theories is that we should be more inclined to imitate people who look like us than people who do not (Cracco et al., 2018; Press, 2011). Supporting this view, there is now robust evidence that automatic imitation is stronger for human agents, who look like us, than for non-human agents, who do not (Bird et al., 2007; Liepelt et al., 2010; Press et al., 2005, 2006). This animacy bias was recently confirmed in a meta-analysis showing that automatic imitation increases gradually as the observed agent becomes more human-like (Cracco et al., 2018).

What is less clear, however, is whether automatic imitation is also modulated by *beliefs* about animacy. In one of the first papers investigating this question, Liepelt and Brass (2010) replaced the traditional human hand with an ambiguous, gloved hand. Half of the participants were told that the hand was a human hand, whereas the other half was told that the hand was an animated wooden hand. The results revealed that automatic imitation was stronger when participants thought the hand was human than when they thought it was not, suggesting a top-down influence of animacy beliefs on automatic imitation (Liepelt et al., 2008; Liepelt & Brass, 2010; Wang & Hamilton, 2012). Similar modulations of automatic imitation by animacy beliefs have also been obtained in other research. For example, two studies looking at automatic imitation of dot movements found that participants only imitated the dots if they believed their movements were generated from human movement (Stanley et al., 2007) or if there was a still image of a human in the background signaling human agency (Sparks et al., 2016). Likewise, other research found that automatic imitation of moving objects was stronger when participants were told the movements were generated from human finger movements (Gowen et al., 2016) and that automatic imitation of a virtual hand was weaker when the instructions mentioned the hand was computer-generated (Longo & Bertenthal, 2009). Finally, one study found that bottom-up and top-down animacy cues may interact, with imitation being reduced only if two conditions are met: the hand is a non-human hand and participants believe its movements are computer-generated (Klapper et al., 2014).

Together, these findings led to the view that social beliefs and expectations help shape the processing of other people's actions (Gowen et al., 2016; Hortensius & Cross, 2018; Teufel et al., 2010). However, not all research has come to the same conclusion (Cracco et al., 2018; Press et al., 2006). For example, Press et al. (2006) showed participants either a human or robotic hand while telling them, in two separate sessions, that the hand’s movements were human or robot movements. The results revealed a bottom-up (i.e., appearance) but no top-down (i.e., beliefs) modulation of automatic imitation. Likewise, in a recent meta-analysis, Cracco et al. (2018) found no clear effect of animacy beliefs on imitative responses. In particular, the results indicated that there was insufficient evidence on either side, with support for neither the presence nor absence of a top-down animacy effect. In other words, there is currently inconsistent evidence on the role of animacy beliefs in automatic imitation. Most of this evidence has, furthermore, been obtained with relatively small samples. In contrast, comparable pre-registered research suggests that belief manipulations should not be expected to have more than a modest effect (e.g., Genschow, Rigoni, & Brass, 2017).

Given the inconsistent evidence, and in light of the replicability debate (Open Science Collaboration, 2015), the aim of the current study is to provide a stringent test of the role of top-down beliefs in automatic imitation by conducting a high-powered registered replication of the study by Liepelt and Brass (2010). Our decision to focus on this study was motivated by three reasons: (a) it is one of the most prominent and most cited studies on the topic, (b) its computerized procedure makes it less prone to bias and more convenient to test in larger samples, and (c) by using an ambiguous rather than an unambiguous human or non-human hand, it arguably measures a purer belief effect and leaves open more room for such effects to influence automatic imitation. If automatic imitation is sensitive to top-down animacy beliefs, it should be weaker when participants think the hand is a wooden hand than when they think it is a human hand. In addition, we also aim to extend Liepelt and Brass (2010) by exploring a potential underlying mechanism for the belief effect. Specifically, we will test the hypothesis that the influence of animacy beliefs on automatic imitation runs via perceived similarity. This hypothesis is consistent with the model of Gowen and Poliakoff (2012), who speculated that automatic imitation is modulated by a self-other comparison process that is informed not only by bottom-up (e.g., visual form) but also by top-down (e.g., beliefs) factors.

Method

Participants

We will test 202 students from the University of Cologne. This provides us with 95% power to detect the group x congruency interaction effect observed by Liepelt and Brass (2010) with a one-tailed tests at $\alpha = 0.05$, after adjusting this effect for uncertainty and potential publication bias[1] with an assurance rate of 80%, using the BUCSS package in R (Anderson et al., 2017). The bias-adjusted effect size is $d_s = 0.47$. Thus, the current study has 95% power to detect $d_s = 0.47$ with a one-tailed test at $\alpha = 0.05$. More generally, the bias-adjusted effect size is more than three times smaller than the original effect size ($d_s = 1.46$) and the planned sample more than 10 times larger than the original sample (N = 19). Using a sample of N = 202, all effects with an observed effect size $d_s \geq 0.23$ will be significant. Given that effect sizes $d_s \leq 0.30$ are typically considered small effects, this implies that the current study is not only powered to detect the previously observed effect, but also to detect relatively small effects in general. Excluded participants will not be replaced unless $N_{excluded} \geq 20$ (i.e., 10% of the total sample). In this case,

[1] Note that this should not be taken as evidence that publication bias played a role in the study of Liepelt and Brass (2010) but rather as a conservative approach that corrects for all sources of bias that *may* have inflated the reported effect size.

$N_{excluded}$ additional participants will be tested, and this procedure will be repeated until the final sample is N > 182.

Design

In line with Liepelt and Brass (2010), the experiment consists of a between-subjects factor for animacy belief (human vs. wooden hand) and a within-subjects factor for congruency (congruent vs. incongruent trials). Participants will be allocated randomly to the human or wooden hand group using a procedure that ensures an equal number of participants in both groups (before exclusions).

Task and Procedure

The experiment is an exact replication of Liepelt and Brass (2010), except that we will (a) use a different glove and different stimuli[2], (b) reprogram the experiment in Psychopy (Peirce et al., 2019), (c) include three new self-report items, and (d) slightly rephrase some other items. The first change was implemented because the original glove could not be retrieved, the second change for compatibility reasons, the third change to test for potential mediators, and the fourth change to

[2] To validate these new stimuli, we ran an online pilot study with 20 participants (9 female, M_{age} = 24, SD_{age} = 4.27). The procedure of the pilot study differed from the procedure of the actual study to make it more appropriate for online testing. In the pilot study, a picture of the hand in resting position was presented for 500 ms, followed by a picture of the hand lifting the index or middle finger together with the number 1 or 2 for 2000 ms or until response. Participants responded by releasing the G or H key on the keyboard. The pilot study also contained a minimal animacy belief manipulation. Specifically, participants were told in the instructions that the hand in the glove was either a human (N = 9) or a wooden hand (N = 11) and this was demonstrated using Fig 1a and Fig 1b from Liepelt & Brass (2010). Two participants from the human hand group were excluded because they indicated that they did not use their right hand. The data of the remaining 18 participants were analyzed in the same way as in the actual experiment, using one-tailed paired *t* tests. The congruency analysis indicated that RTs were significantly faster, $t(17) = -10.78$, $p < .001$, and ERs significantly lower, $t(17) = -5.65$, $p < .001$, on congruent than on incongruent trials. This confirms that the new stimuli are able to elicit automatic imitation. The group analysis indicated that the congruency effect was larger in the human hand group than in the wooden hand group for RTs, $t(17) = 1.91$, $p = .041$, but not for ERs, $t(17) = 1.18$, $p = .129$, although the RT and ER effects went in the same direction. The pilot study thus replicates the results of Liepelt & Brass (2010).

improve the manipulation check. The experimental program is available on the OSF (https://osf.io/v2wyu/).

In the experiment, participants will do an automatic imitation task requiring them to lift their right index finger when they see the number ‘1’ and their right middle finger when they see the number ‘2’ while, at the same time, a right hand positioned in the first-person perspective and wearing a black glove performs the same (i.e., congruent) or a different (i.e., incongruent) action (Figure 1). Automatic imitation in this task is measured as a congruency effect, with faster responses on congruent than on incongruent trials (Cracco et al., 2018). Participants will be seated at a distance of approximately 80 cm from the screen, with the images displaying the hand and response cue (i.e., ‘1’ or ‘2’) subtending an angle of 14° x 10°. Each trial will start with a picture of the hand in resting position for 800 ms. Next, this picture will be replaced by a second picture showing the hand lifting either the index or middle finger, together with the number ‘1’ or ‘2’ presented in between the two fingers for a duration of 1,915 ms. Responses will be registered with an optical response box that records when the finger leaves the sensor. To signal response registration, all responses will be followed by a 50 ms tone. After 1,915 ms, a blank screen will be presented for 2,100 ms.

To manipulate animacy beliefs, the imitation task will be preceded by a belief induction phase. In this phase, participants will be shown a human or wooden hand wearing a leather glove and will be told that they will also see a human/wooden hand during the experiment. In reality, however, all participants will see the same gloved stimulus hand (Figure 1). In the *human hand condition*, the exact wording will be: “You will see photos of a human hand in a glove, lifting either its index or middle finger, made by photographing the hand in these different positions”. While giving these instructions, the experimenter will put the glove on her own hand and lift her index and middle fingers two times as a demonstration. In the *wooden hand condition*, the exact wording will be: “You will see photos of a wooden hand in a glove, with its index or middle finger lifted, made by photographing the hand in these different positions”. While giving these instructions, the experimenter will put the glove on the wooden hand and will lift its index and middle fingers two times as a demonstration. Following belief induction, the experimenter will then explain the experimental task, before again repeating the human/wooden hand instruction, except that she will now just show the human/wooden hand without demonstrating the finger lifting movements. Finally, she will start the experiment. The complete instruction script can be found in Supplementary Material.

In the experiment, participants will first see a brief summary of the task instructions on the monitor. Next, they will do a practice phase of 10 trials, in which task performance will be monitored by the experimenter, followed by two experimental blocks, in which performance will no longer be monitored. If accuracy on the practice phase is below 70%, the practice phase will repeat. The experimental blocks will consist of 60 congruent and 60 incongruent trials, presented at random, adding up to a total of 240 trials. Between the two blocks, participants can take a self-paced break.

After the experiment, participants will be asked to indicate on a 5-point scale (a) how similar the stimulus hand was to the model hand, (b) how self-propelled the stimulus hand was, (c) how similar the stimulus hand was to their own hand, and (d) how much they had attended to the stimulus hand. In addition, participants in the human hand group will be asked whether they thought the stimulus hand was a human hand using a simple yes or no question. Similarly, participants in the wooden hand group will be asked whether they thought the stimulus hand was a wooden hand. The first two questions were based on Liepelt and Brass (2010), with the following differences: the first question originally asked about the similarity between the "situations" depicted in the instructions and experiment. The word "situation" was changed to "hands" to make the question more concrete. The second question originally asked about the extent to which the "human hand" or "wooden hand" was self-propelled. This was changed to "hand" not to bias responses. In addition, the wording of the original questions was changed so that all questions had a similar grammatical structure. The last three questions were novel questions. Questions (c) and (d) were included to explore potential mediators. Question (e) was included to obtain a direct measure of the extent to which the manipulation worked. The exact questions are available in Supplementary Material.

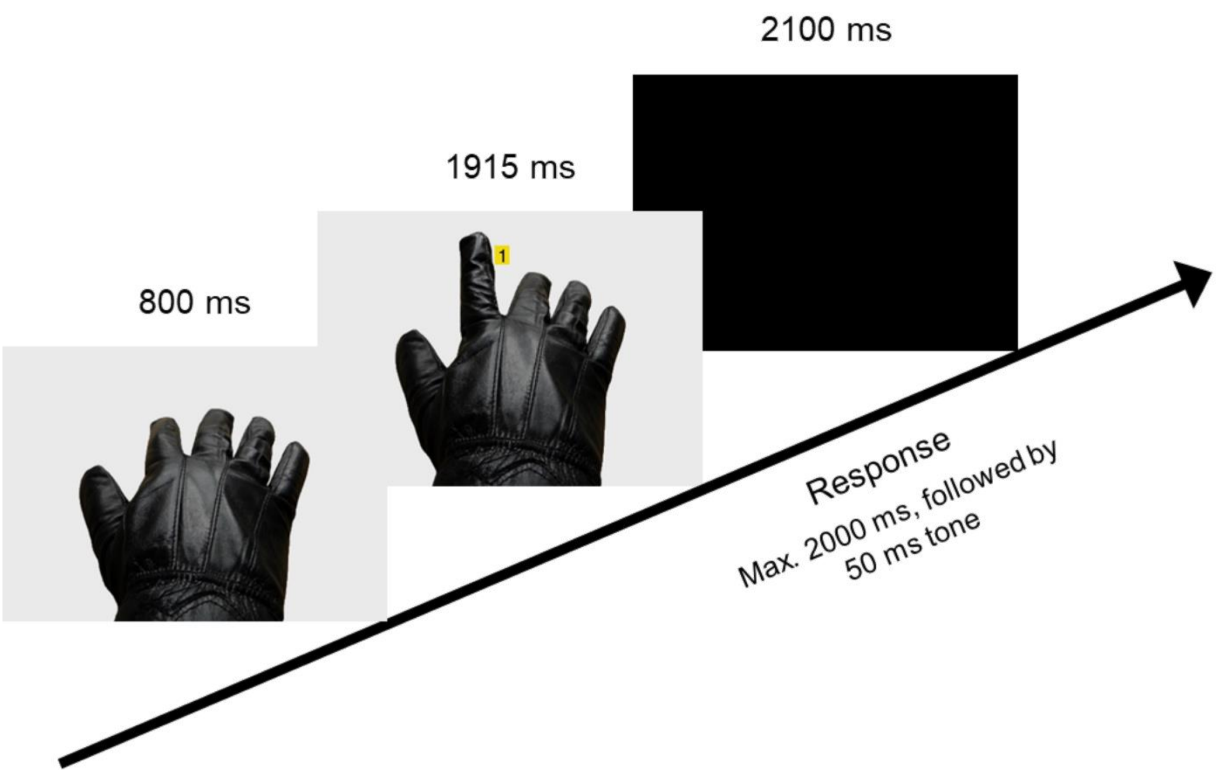

Figure 1. Procedure of each trial. Each trial starts with a picture of the hand in resting position for 800 ms. This picture is then replaced with a picture of the hand lifting either the index or middle finger, together with the number 1 or 2 for

1915 ms. Participants have 2000 ms to respond following the presentation of the second image. Responses are followed by a 50 ms feedback tone. Each trial finishes with a 2100 ms intertrial interval.

Trial Exclusion

In line with Liepelt and Brass (2010), we will exclude all trials in which the response is incorrect or slower than 2,000 ms from the reaction time (RT) analysis and all trials with a response slower than 2,000 ms from the error rate (ER) analysis. In addition, we will exclude participants with an ER exceeding 15%. No other participants or trials will be excluded.

Preregistered Analyses

The significance level for all statistical tests is set to $\alpha = 0.05$. An R script detailing the planned analyses on a simulated dataset is available for review on the OSF: https://osf.io/v2wyu/.

Manipulation Check

To test whether beliefs were successfully manipulated, we will first look at the perceived similarity between the stimulus and model hand. Based on the ratings reported by Liepelt and Brass (2010), we expect the perceived similarity to be high, with a mean rating around 4 out of 5. We will then test whether these ratings differ between groups using a two-tailed Welch's independent samples *t* test. We expect no significant difference between the two groups. Second, we will test whether the intentionality ratings (i.e., the extent to which the hand appeared self-propelled) differ between groups using a one-tailed Welch's independent samples *t* test. We expect a significant difference between groups, with participants in the human hand group rating the hand as more intentional than participants in the wooden hand group. Third, we will test if attention ratings differ between groups using a two-tailed Welch's independent samples *t* test. We expect no differences between groups. Finally, we will test if the stimulus hand was perceived as a human hand in the human hand group and as a wooden hand in the wooden hand group using a logistic regression with the frequency of yes/no responses as dependent variable and group as a between-subjects factor. We expect a significant intercept, with more yes than no responses, but no significant effect of group.

Confirmatory Analyses

Our main predictions are (a) an RT congruency effect (b) that is larger in the human than in the wooden hand group. To investigate the first prediction, we will investigate if RTs on incongruent trials are slower than RTs on congruent trials, using a one-tailed paired samples *t* test. To investigate the second prediction, we will test if this congruency effect is larger in the human than in the wooden hand group, using a one-tailed Welch's independent samples *t* test. We will refer to these two analyses as the "congruency analysis" and the "group analysis", respectively. Note that we will report *t* tests instead of a group (human or wooden) x congruency (congruent or incongruent) mixed effects ANOVA because this allows us, on the one hand, to increase statistical power by using one-tailed tests and, on the other hand, to correct for unequal variances using Welch's correction.

If the group analysis is significant, we will follow up on this result by separately testing the congruency effect in the human and wooden hand groups using two one-tailed paired *t* tests. We expect RTs to be significantly slower on incongruent than on congruent trials in both groups. If the group test is not significant, we will follow up with an inferiority test investigating whether the observed group effect is significantly smaller than $\Delta_s = 0.35$ (Lakens et al., 2018). The bound of $\Delta_s = 0.35$ is motivated by the fact that this is the effect size our sample can detect with 80%

power using a one-tailed test at α = 0.05. In other words, if the inferiority test is significant, this would mean that the effect of animacy beliefs on automatic imitation, if it exists, is smaller than d_s = 0.35 and therefore that future studies would need samples with N > 202 to realistically detect this effect.

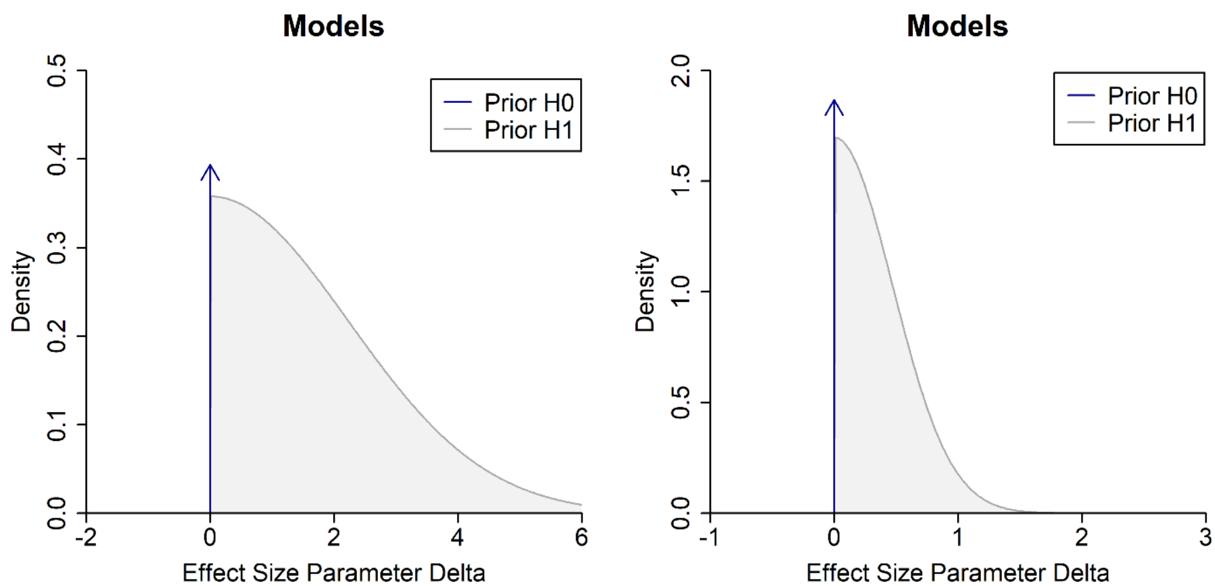

Figure 2. Priors used for the Bayesian analyses on the RTs. The left plot shows the prior used in the congruency effect analysis. The right plot shows the prior used in the group analysis.

Finally, to obtain a more comprehensive overview of the evidence, we will accompany our two main statistical tests with Bayes factors (BFs) comparing the likelihood of the data under the alternative and null hypotheses. The null hypothesis is a point null hypothesis. The alternative hypothesis is a half-normal distribution centered on d_s = 0 and with an *SD* set to the bias-adjusted effect size of the corresponding effects reported by Liepelt and Brass (2010), as suggested by Dienes (2014). This means that the *SD* is set to d_s = 2.23 for the congruency analysis and to d_s = 0.47 for the group analysis. The choice for half-normal distributions is motivated by the fact that we have clear directional hypotheses, the choice to center the distributions on d_s = 0 by the conservative assumption that smaller effects are more plausible than larger effects, and the choice to set the *SDs* to the bias-adjusted effect sizes in Liepelt and Brass (2010) by the fact that this assumes a largest plausible effect that is approximately twice the original, bias-adjusted effect (i.e., d_s = 4.46 and d_s = 0.94).

Exploratory Analyses

Overall RT Difference. In a first exploratory analysis, we will test whether RTs are different in the human and wooden hand conditions using a two-tailed Welch's independent samples *t* test. We will use a two-tailed test because we have no strong hypothesis. Nevertheless, based on previous work, one could expect slower responses in the human hand group. Such an effect was found by Liepelt and Brass (2010) and a similar effect was also obtained by Gowen and colleagues (2016), who found that participants responded more slowly when they believed that stimuli depicting a moving object were generated from finger movements compared to when they did not.

Error Rate Analysis. In a second exploratory analysis, we will analyze ERs using the same procedure as the one described for RTs, with the exception that we will use different *SD*s for the Bayesian prior distributions. The prior *SD* for the Bayesian congruency analysis will be set to the bias-adjusted effect size of the ER congruency effect (*SD* = 0.81) reported by Liepelt and Brass (2010). In contrast, the prior *SD* for the Bayesian group analysis will be set to half the bias-adjusted effect size of the RT group x congruency interaction (i.e., *SD* = 0.24) reported by Liepelt and Brass (2010) because no estimate of the (non-significant) ER group x congruency interaction was reported.

Sensitivity Analysis. Because data-analysis inevitably involves a series of relatively arbitrary decisions (Steegen et al., 2016), we will investigate in a third set of exploratory analyses to what extent the RT and ER results are robust to variations in the applied exclusion criteria and analysis methods. First, we will repeat the analyses after excluding participants who did not consider the stimulus and model hands to be similar (i.e., ratings ≤ 3). Second, we will repeat the analyses after excluding participants in the human hand group who did not think the hand was a human hand and participants in the wooden hand group who did not think the hand was a wooden hand. Third, we will repeat the analyses after excluding trials with an RT exceeding participants' mean RT with more than 3 SDs. Finally, we will replace the parametric tests with their non-parametric variants: the Mann-Whitney U test for independent samples *t* tests and the Wilcoxon-signed tank test for paired samples *t* tests. For this last analysis, we will only repeat the frequentist analyses because we are not aware of any readily available packages to run Bayesian non-parametric tests with informed priors.

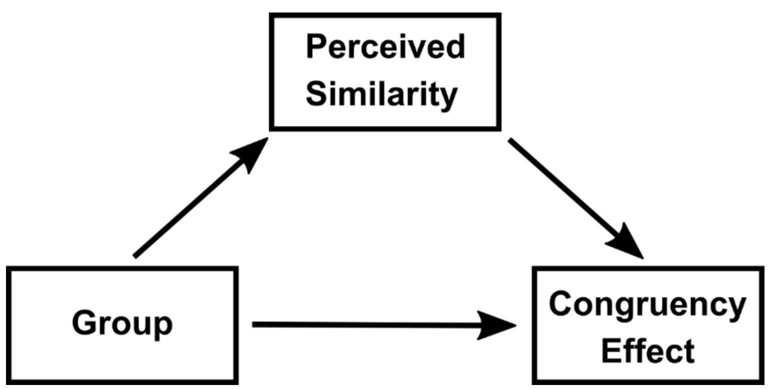

Figure 3. Path model used to test whether perceived similarity mediates the effect of group on the RT congruency effect.

Mediation Analysis. Finally, we will explore whether perceived similarity between the stimulus hand and the own hand mediates the effect of animacy beliefs on the RT congruency effect by testing the path model shown in Figure 3 with the lavaan package in R (Rosseel, 2012). More specifically, we will test if there is a significant indirect effect of group (human vs. wooden hand) on the RT congruency effect via perceived similarity using a Sobel test with bootstrapped standard errors (1000 bootstraps). If confirmed, we will then test if the direct effect of group on the RT congruency effect is still significant after accounting for the indirect effect via perceived similarity. In addition, although we primarily expect perceived similarity to act as a mediator, we will also run separate mediation analyses with intentionality and attention ratings as mediators. If any of these analyses reveals a significant mediation, we will follow up on these analyses by fitting a model including all individually significant mediators to investigate which of them explains unique variance.

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