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Methodological issues in measures of imitative reaction times

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Running head: Imitative reaction times

Abstract

Ideomotor (IM) theory suggests that observing someone else perform an action activates an internal motor representation of that behaviour within the observer. Evidence supporting the case for an ideomotor theory of imitation has come from studies that show imitative responses to be faster than the same behavioural measures performed in response to spatial cues. In an attempt to replicate these findings, we manipulated the salience of the visual cue and found that we could reverse the advantage of the imitative cue over the spatial cue. We suggest that participants utilised a simple visuomotor mechanism to perform all aspects of this task, with performance being driven by the relative visual salience of the stimuli. Imitation is a more complex motor skill that would constitute an inefficient strategy for rapid performance.

Introduction

The topic of movement imitation has received much attention within the research literature over recent years (for reviews see Brass & Heyes 2005; Jacob & Jeannerod 2005; Rogers and Williams, 2006), not least because of its likely importance in the development of social cognition. One central question within imitation research is how an imitator selects the pattern of motor activity that matches an observed movement (the so-called ‘correspondence problem’). A number of competing theories provide possible solutions to the correspondence problem. One influential framework is provided by ideomotor (IM) theory (Greenwald 1970a, 1970b) with other approaches adopting IM as a starting point (e.g. Bekkering et al, 2000, proposed a goal directed theory of imitation that built directly upon IM). Ideomotor theory suggests that observing someone else perform an action activates an internal motor representation of that same behaviour within the observer, by virtue of the shared perceptual contents of the observation and the internal representation of the action (which, by hypothesis, includes a representation of the perceptual consequences of the action in question).

Evidence for the existence of ‘mirror neurons’ (MNs) that might serve such a function has come from a range of neurophysiological and neuroimaging studies of human and non-human primates (Rizzolatti et al, 2001 ; Buccino et al, 2001), and the nature of these neurons has motivated much behavioural work. Nevertheless, whilst MNs have been shown to serve action-understanding their role in imitation is less clear. Monkeys with MNs do not imitate and thus simple matching of perceived action to motor representation appears to be insufficient for imitation to occur. Rather, imitation is a complex function that requires intentional commission rather than simple removal of inhibitory function.

There is behavioural evidence, however, that disputes this position and suggests that observation does activate a matching action representation. Several recent studies have purported to measure such activation by measuring changes in reaction time (RT) as a function of the ideomotor compatibility between the observed and performed action. For example, Brass et al (2000) found that when participants were required to execute a simple finger movement (lifting the index or middle finger), they were faster to react if they observed that same movement than if they observed a static image of the finger with a cross marking the finger. In addition, if the stimulus showed a moving finger that was to be ignored, reaction times were faster if the irrelevant movement was congruent to the movement to be performed, and slower when it was incongruent. This would suggest that the path from stimulus perception to executed action was shorter for imitation than for a simple learnt stimulus-response relationship. This therefore offers direct support for IM (see e.g. Brass & Heyes 2005). Brass, Bekkering & Prinz (2001) and Stürmer, Ascherleben & Prinz (2000) have also found similar evidence.

Nevertheless, there are questions that need to be addressed when using experimental designs that use RT. RT is affected by a range of factors that need to be matched across conditions (for a review see Schmidt & Lee 1999). One such factor is the visual salience of the imperative stimulus; participants are faster to respond, for instance, to larger targets or targets with higher contrast. Studies that have investigated ideomotor compatibility tend to use an object like a cross or a square as a control for a hand or finger movement – these are generally not chosen to control for salience, and any mismatch may have consequences for interpreting the data. We therefore investigated the effect of visual salience on reaction-time differences between imitative and spatial cue conditions in a replication of Brass et al (2000). The crucial question was whether spatial cues would be reliably slower than imitative cues when visual salience was altered. The first experiment aimed to replicate the basic result from Brass et al; the second tested what happened to that effect when the visual salience of the spatial cue was increased; and the third experiment placed ideomotor compatibility and visual salience in direct competition.

Methods

Twenty-four right-handed students (mean age 21.4 years) participated in one of three experiments (eight students randomly assigned to each experiment). All participants provided their informed consent prior to their inclusion in the study. The study was approved by the University ethics committee and was performed in accordance with the ethical standards laid down in the Declaration of Helsinki. The experiments were designed to replicate all crucial elements of the study originally conducted by Brass et al (2000).

Experiment 1

Participants placed their head in a chinrest at a fixed distance of 90cm from the screen. They placed the index and middle fingers of their right hand on top of two marked keys on a keyboard. In all three experiments, finger movement was the relevant stimulus dimension (and instruction given) for Block 1. For Block 2, the presentation of a spatial cue (an 'X' marked on either the index or middle finger of the hand in the picture) was the relevant stimulus dimension (and therefore instruction). Block order presentation was counterbalanced across participants.

Each trial began with the presentation of a blue screen for 500ms. This was followed by an image of a motionless hand remaining on screen for 560ms, identical for every trial in both blocks within an experiment. The picture of the hand (7x7cm) was orientated so as to appear as the mirror image of the participant’s own right hand resting on the keyboard positioned in front of the participant. Each block consisted of three conditions. In the first condition in the finger movement block, either the index finger or middle finger was shown pressing down on the computer key (the ‘movie’ took approximately 100ms) after the frame showing the motionless hand. Participants were told to press the key according to which finger they saw pressing down. In two further conditions an X was shown on the nail of the fingertip that was either congruous or incongruous with the finger movement, which subjects were instructed to ignore (see Figure 1 for example stimuli). The spatial cue block consisted of the same stimuli but participants were asked to respond to the spatial cue and to ignore the finger movements. The two counter-balanced blocks therefore consisted of six conditions: an index finger cue and a middle finger cue both of which were either congruent, baseline or incongruent for the instruction given. Each condition was presented randomly 20 times within each block whilst 12 practice trials (two for each condition) preceded the 120 trials in each block.

In Experiments 1 and 2, the initial image consisted of both the index and middle fingers raised above their corresponding keys. In Experiment 3, the initial image featured both fingers rested on their keys. Participants were asked to respond to stimuli presentations as quickly as possible and

'not to worry about making mistakes'. The stimuli were presented using customised software that generated the image frames on screen (800 by 600 pixels, 16 bit colour, 85Hz refresh rate) whilst measuring response times to those images. RT was measured as the time taken to press the correct key after stimulus presentation. Errors were considered to be incorrect responses as were responses where reaction times were less than 150ms or more than 800ms. Errors were counted and then excluded from RT analysis. For each experiment, an ANOVA was computed with two within-participant factors, using type of instruction (finger movement condition vs. spatial cue condition) as the first factor and congruency (congruent, baseline and incongruent) as the second factor.

Experiment 2

In Experiment 2, the visual salience of the 'X' used for the spatial cue was altered. We increased the size of the X by a factor of two. In all other respects the experiment was identical to the first.

Experiment 3

This experiment was designed with a parallel logic to Experiment 3 from Brass et al (2000). In that experiment, they reduced the amount of ideomotor compatibility between the irrelevant dimension and the task to be performed, finding that this reduced the effect of the compatibility of the (irrelevant) finger movement on response times. They did this by keeping the stimuli the same but changing the task (a tap, instead of a downward flexion).

In the current Experiment 3, we wanted to reproduce the relative visual salience of the cues from Experiment 1, but change the ideomotor compatibility. We kept the task the same (a key press) but altered the video. The video clip for this experiment contained the same frames as those from Experiment 1, but this time played in reverse order so that the finger moved up away from the key. This kept the relative visual salience of the finger and cross identical to the presentation in Experiment 1, but the demonstrated action was incompatible with the required response. IM theory predicts that the ease with which a stimulus can be transformed into an action depends on the similarity between the observed event and the executed action. In situations where an observed action matches the required reaction, this similarity is maximal (Greenwald 1970). If the compatibility effect of the (irrelevant) finger movement noted in Brass et al is being caused by the relative visual salience between the finger and cross then we predicted that Experiment 3 would reproduce the effect; if it is being caused by ideomotor compatibility, then we should replicate Brass et al's Experiment 3.

Results

Experiment 1

We first considered error scores. There was no interaction for error score between instruction (spatial cue or finger movement) and congruency. There was no reliable main effect of instruction. Congruency caused a reliable difference in error scores, such that congruent mistakes (2.75) were less than baseline (3.31) which were in turn less than incongruent (5.31) [$F_{(2,14)} = 5.646$, $p<0.05$].

We next considered reaction times (Refer to Figure 2b; Figure 2a shows the data from Brass et al, 2000 for comparison). RT analysis revealed an interaction of instruction type and congruency, such that when the irrelevant and relevant cues were congruent, RT was faster than baseline, whereas when relevant and irrelevant cues were incongruent, RT was slower than baseline [$F_{(2,14)} = 8.744$, $p<0.05$]. A main effect for type of instruction was observed: the finger movement cue evoking a faster overall response than a spatial cue (332 vs. 400). A main effect of congruency was also found: congruent RT (354ms) was less than baseline (360ms) which in turn was less than incongruent (385ms) [$F_{(2,14)} = 13.516$, $P<0.05$]. The pattern of these results is identical to that reported by Brass et al (2000), although the magnitude of the compatibility effect is somewhat reduced.

Experiment 2 – Large X

We first considered error scores. There was no interaction for error score between instruction (spatial cue or finger movement) and congruency. There was no reliable main effect of congruency. There was a reliable main effect of instruction where there was an overall lower error score for the spatial cue (1.54) compared to the finger movement cue (3.21) [$F_{(1,7)} = 14$, $p<0.05$].

We next considered reaction times (refer to Figure 3). RT analysis revealed no interaction of instruction type and congruency. Analysis of RT revealed no reliable effect of congruency but a reliable overall effect of instruction with the spatial cue instruction evoking a faster response than the finger movement instruction (331.75ms vs. 355ms)

[$F_{(2,14)}$ = 12.244, $p<0.05$]. This experiment therefore, demonstrated the opposite pattern of results to Experiment 1, with respect to instruction set: a spatial cue evoked a faster response than a finger movement cue.

Experiment 3 – Reversed Movie

We first considered error scores. Error analysis revealed a reliable two-way interaction between instruction and congruency [$F_{(2,14)}$ = 5.190, $P<0.05$], where the incongruent spatial condition caused greater errors (mean 10.3 errors) compared to the other conditions (with error scores of 2.9 and 4.5). This finding demonstrates that the presentation of an irrelevant incongruent finger movement caused the most errors.

Next, we considered reaction times (refer to Figure 4). RT analysis revealed a significant two-way interaction between instruction and congruency [$F_{(2,14)}$ = 19.619, $p<0.05$]. The finger movement cue evoked a 70ms faster response (331ms) than the spatial cue (401ms). A reliable effect of congruency was found with congruent producing faster RT (349ms) than baseline (365ms), which in turn was faster than incongruent (385ms).

Discussion

Experiment 1 replicated the findings of Brass et al (2000). Participants were faster to react to a finger movement than a spatial cue, suggesting that observation of a finger movement does have a direct facilitating effect on the execution of that same action. However, Experiment 2 demonstrated that increasing the size of the spatial cue reverses these differences, indicating that the RT effects are actually subject to the visual salience of the stimuli. In the absence of salience equality (as in Experiment 1 of both the current work and Brass et al) differences in RT can (and by Occam's razor, should) be explained by the disparities in visual processing.

Experiment 3 then provided a strong test case for the contributions of IM versus visual salience, with the visual salience kept the same as in Experiment 1 but with the ideomotor compatibility reduced (the only difference between Experiment 1 and 3 was the direction in which the 'movie' was played). A reversal in the pattern of findings from Experiment 1 would have provided strong support for IM, but we reproduced the same pattern of results as Experiment 1. We take the consistency of results between Experiments 1 and 3 as confirmation of the result from Experiment 2, that the differences between the finger movement and spatial stimuli are best ascribed to differences in visual salience.

Experiment 2 was not an exact reversal of the pattern seen in Experiment 1. We did reverse the effect of instruction (such that the irrelevant finger movement was now easier to ignore) but did not produce an effect of congruency, which might perhaps have been expected. If the large spatial cue was strong enough to reverse the former effect, it perhaps could have been strong enough to reverse the latter. One interpretation of our result suggests that in the original setup (Experiment 1) the visual salience of the finger simply overwhelmed the salience of the cross; doubling the size of the cross made the salience slightly more even, but was not enough to make the cross able to overwhelm the finger. A more likely explanation of the difference between the Brass et al (2000) result and our own, however, comes from the fact that Brass et al presented their conditions in a blocked design and in a fixed order for all subjects: 40 baseline trials, 40 congruent trials, 40 incongruent trials, whereas we presented the conditions in random order within a block. The difference in baseline RTs between the finger and spatial cue conditions suggests that the cross was simply harder to detect (participants were slower). When there was a block containing congruent finger movements, participants therefore likely just responded to the more salient finger, and hence RT in the two congruent conditions were identical. In the final block, when the finger movement was incongruent, participants most likely detected the more salient finger movement and then executed the opposite response, leading to the RT deficit. When we randomized the presentation, this strategy could not work and participants had to detect the less salient cross, even in the congruent condition, which led to longer RTs. This difference and our account for it are completely compatible with our proposal that visual salience is driving the observed differences in RT.

In conclusion, the results of this experiment show clearly that reaction time differences in imitative and other motor-responses to spatial and movement cues may arise simply as a result of disparities in visual salience of the stimuli. In the absence of such disparities, reaction times will be similar. When the task was not imitative (Experiment 3) reaction times were similar to those in Experiment 1 – the pattern of results in Experiment 1 are therefore not informative about imitation or ideomotor compatibility. The simplest explanation to account for all the results is that similar, non-imitative visuomotor skills were being utilised across experiments. Therefore, the data presented here (and by inference the data reported by Brass et al, 2000) do not allow us to draw any conclusions about the pros or cons of ideomotor theory (IM) as an explanatory model for imitation. This concern about visual salience not being controlled also seems likely to influence much of the extant literature: for example, Brass et al (2001) had a 'moving object' condition, but while the object's motion was generated by a person's finger the relative visual salience of the object was less than that of the finger.

This study suggests that caution must be exercised when interpreting behavioural studies. Specifically, much care must be taken to match fundamental factors that influence reaction time (such as visual salience) across conditions when using this measure to show response facilitation. More generally, these data highlight the need to consider carefully whether a more parsimonious general explanation can suffice to explain a behavioural pattern.

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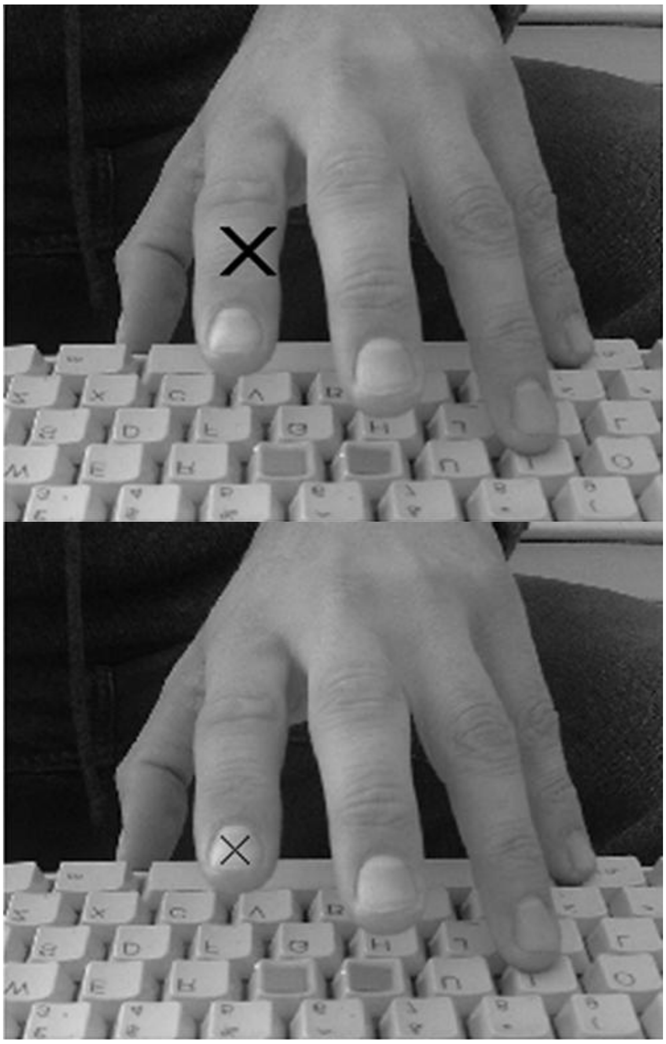
Figure captions

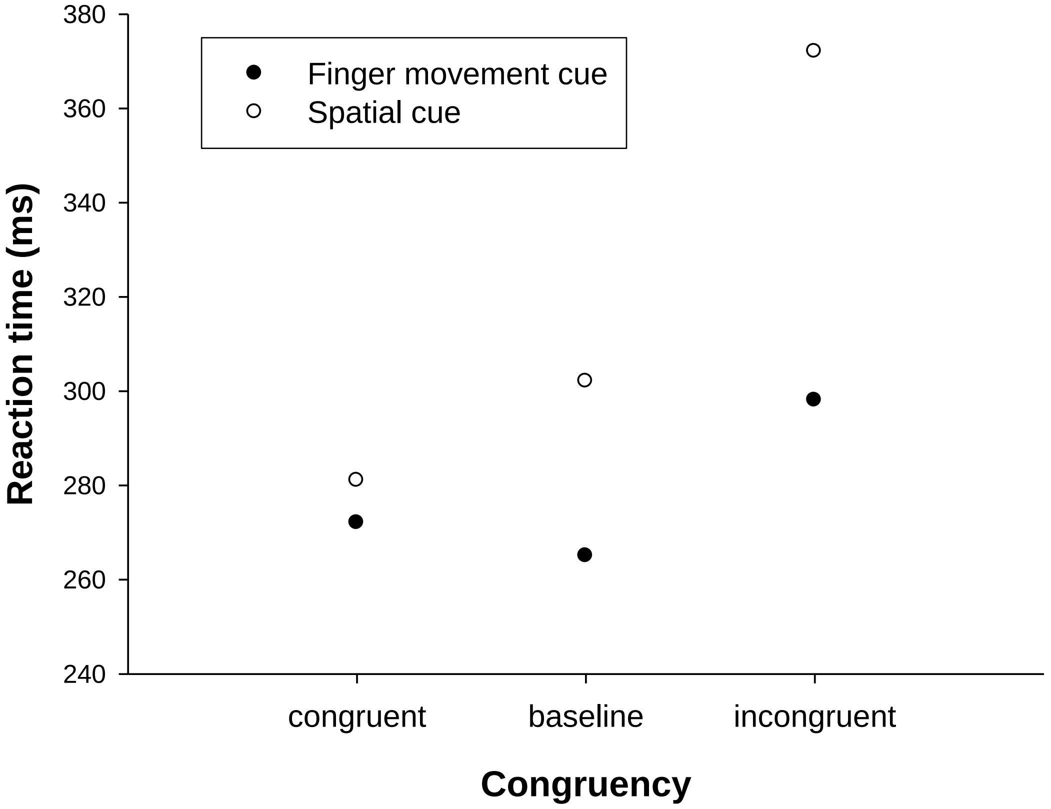
Figure 1. Example stimuli, showing the two different cross sizes.

Figure 2. Reaction time (RT) as a function of congruency (congruent, baseline and incongruent) and type of instruction (finger movement condition and spatial cue condition). Upper graph shows the results from Brass et al (2001). The lower graph shows the results of Experiment 1 in the present study. In the spatial cue condition the observed finger movement was the irrelevant dimension whilst in the finger-movement condition the spatial cue was the irrelevant dimension.

Figure 3. Reaction time (RT) as a function of congruency (congruent, baseline and incongruent) and type of instruction (finger movement condition and spatial cue condition) in Experiment 2. In the spatial cue condition the observed finger movement was the irrelevant dimension whilst in the finger-movement condition the spatial cue was the irrelevant dimension.

Figure 4. Reaction time (RT) as a function of congruency (congruent, baseline and incongruent) and type of instruction (finger movement condition and spatial cue condition) in Experiment 3. In the spatial cue condition the observed finger movement was the irrelevant dimension, while in the finger-movement condition the spatial cue was the irrelevant dimension.

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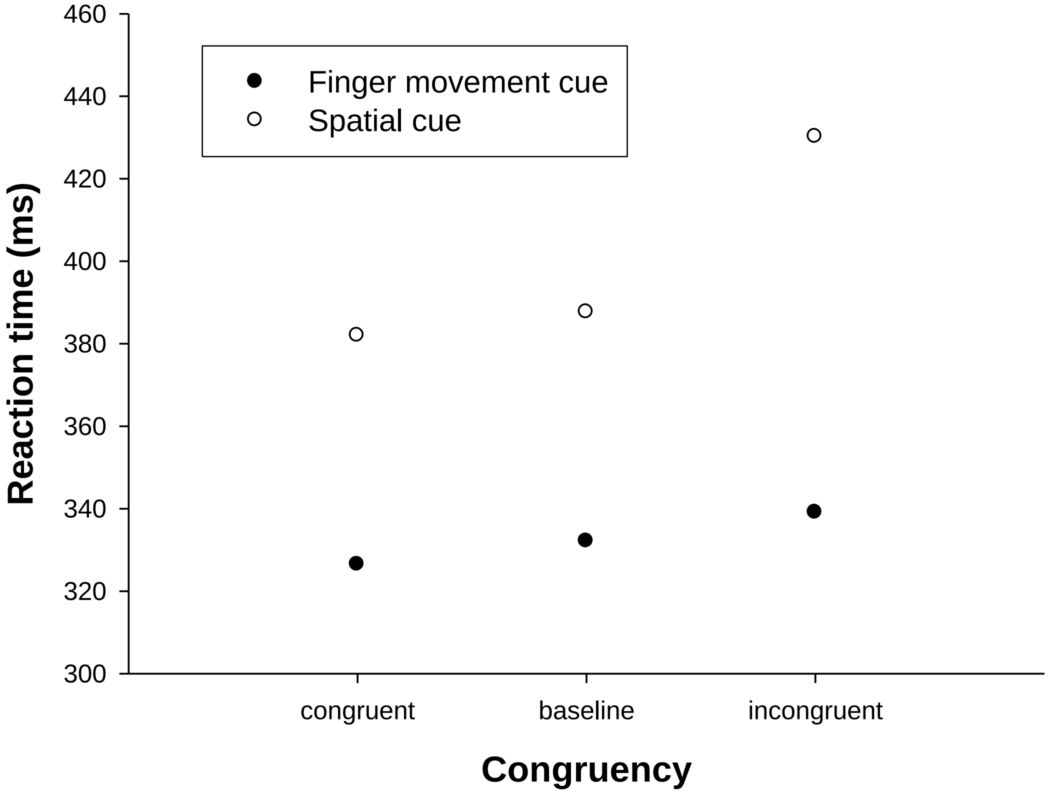
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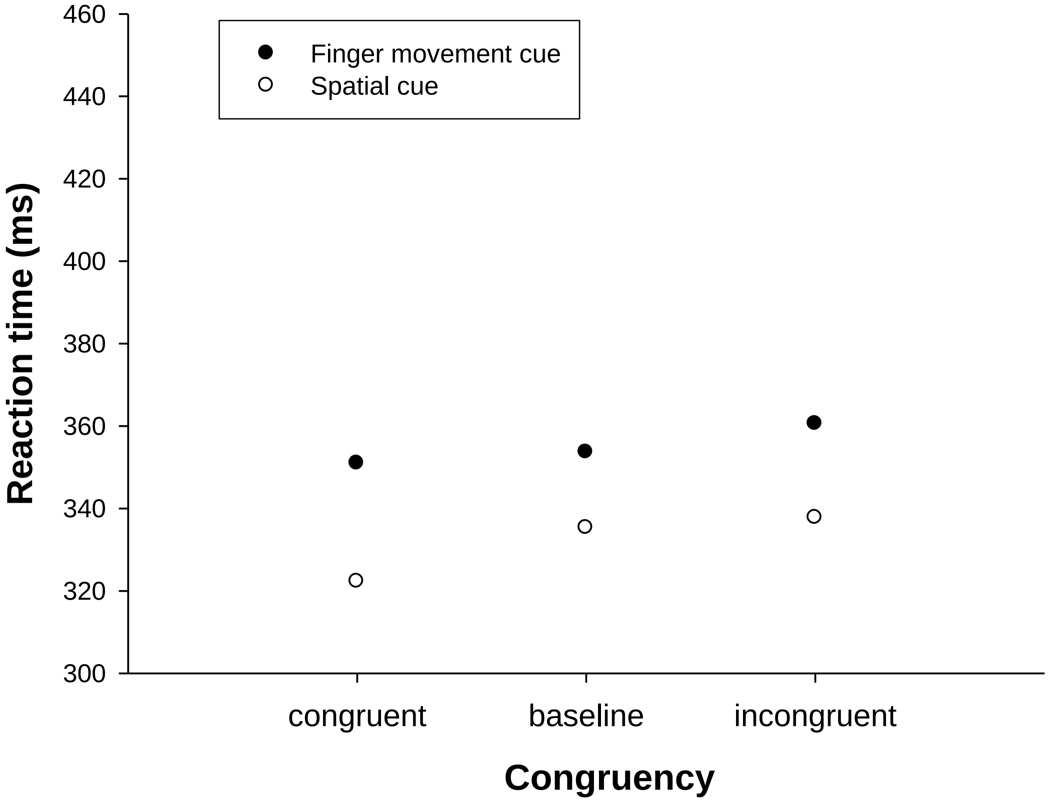
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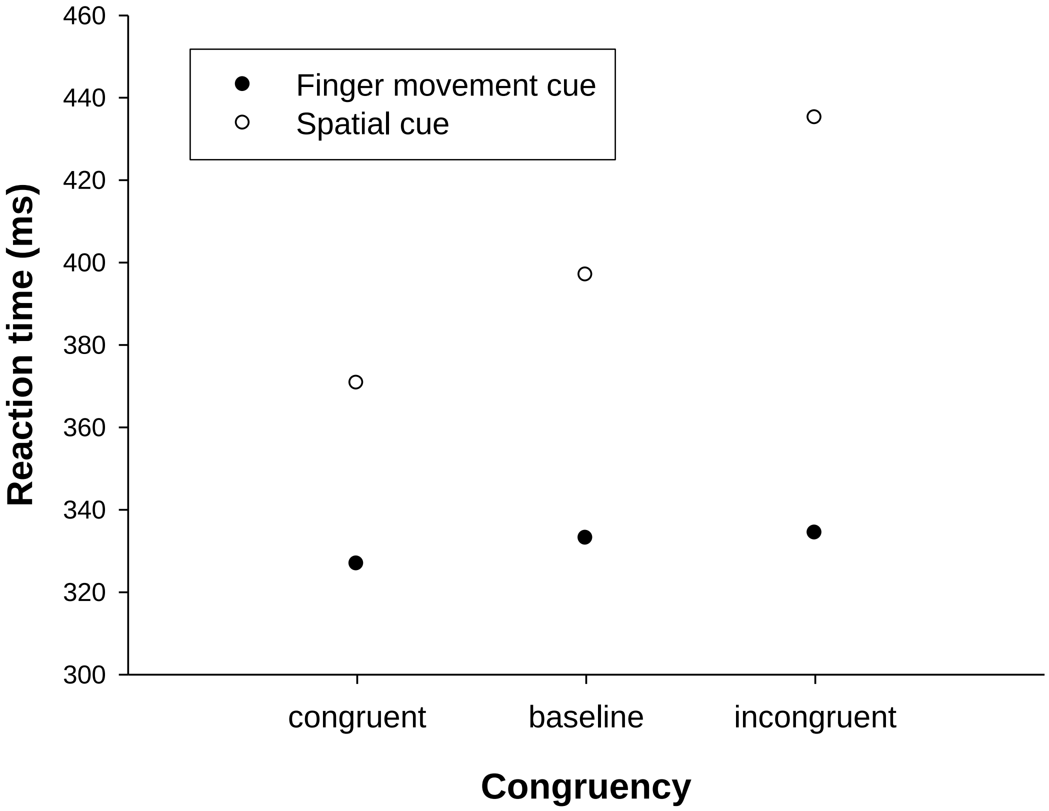
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