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Motor simulation of multiple observed actions☆

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ABSTRACT

Research has shown that observed actions are represented in the motor system, leading to automatic imitative responses. However, in social life, we often see multiple persons acting together. Here, we use an automatic imitation paradigm with four stimulus hands to investigate the hypothesis that multiple observed actions can be represented at the same time in the motor system. Experiments 1 and 2 revealed weaker automatic imitation when one hand performed a different action than the other three hands, compared with when three or four hands all performed the same action. Experiment 3 replicated this effect with mutually exclusive actions. These results show that multiple observed actions can be represented simultaneously in the motor system, even when they cannot be executed together. This has important implications for theories of interaction representation.

1. Introduction

Social cognition crucially requires us to interpret and respond to the actions of others. However, it is often difficult to predict from visual input alone how an action will unfold (Brass & Heyes, 2005). Therefore, it has been proposed that we can predict the course and outcome of observed actions by simulating them in our own motor system (Wilson & Knoblich, 2005). Supporting this idea, research has demonstrated that observed actions are indeed processed in the motor system (Caspers, Zilles, Laird, & Eickhoff, 2010; Gazzola & Keysers, 2009), and that this leads to automatic imitation (Chartrand & Lakin, 2013; Cracco et al., 2018). A prominent task to measure automatic imitation is the imitation-inhibition task (Brass et al., 2000; Stürmer et al., 2000). In this task, participants respond to a symbolic cue by performing an action while a hand on the screen performs either the same action or a different action. The results typically show that responses are faster on congruent trials, where the stimulus action matches the response, than on incongruent trials, where the stimulus action mismatches the response, suggesting that the stimulus hand was imitated (Cracco et al., 2018; Heyes, 2011).

Yet, in social life, we have to represent not only the actions but also the interactions of others. Recently, it was proposed that social interactions may be represented by simulating the actions of the different interactors in the motor system (Quadflieg & Koldewyn, 2017; Quadflieg & Penton-Voak, 2017). However, because research has mainly focused on situations involving a single agent, the underlying assumption that motor simulation can be extended to multiple actions remains to be tested. To address this issue, recent work has started to investigate the role of motor simulation in multi-agent settings (Cracco & Brass, 2018a, 2018b; Cracco, De Coster, Andres, & Brass, 2015, 2016; Ramenzoni, Sebanz, & Knoblich, 2014; Tsai, Sebanz, & Knoblich, 2011). This has revealed that seeing two agents performing the same action produces stronger imitation (Cracco & Brass, 2018a, 2018b; Cracco et al., 2015) and corticospinal excitability (Cracco, De Coster, Andres, & Brass, 2016) than seeing one agent performing a single action, indicating that two observed actions can be represented at the same time in the motor system.

Nevertheless, two identical observed actions might still be represented as a single action. Therefore, a fundamental question is whether two different observed actions can be represented in the motor system as well. Indeed, interacting individuals tend to perform different actions, and these actions might even be mutually exclusive in terms of motor execution. To date, only one study has looked at motor simulation of different actions (Cracco et al., 2015). The results revealed that two agents performing two different actions, one congruent and one incongruent, did not produce any automatic imitation. It was argued that this was because both observed actions were represented in parallel, leading to concurrent facilitation and interference effects that canceled out each other. However, it could also be that neither action was represented.

Therefore, the aim of the current study was to investigate directly whether two different observed actions can be simulated together, and

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to explore whether this depends on bodily constraints. To this end, three experiments measured automatic imitation while participants observed three hands performing one action (“THREE”), four hands performing one action (“FOUR”), or three hands performing one action and a fourth hand performing a different action (“THREE-ONE”). Previous research has revealed that up to four identical actions can be represented using this paradigm (Cracco & Brass, 2018b). If two different actions can be represented as well, automatic imitation should be reduced in the THREE-ONE condition compared with the THREE and FOUR conditions because the fourth hand then counteracts the other three hands. Furthermore, to test the role of motor constraints, Experiments 1 and 2 used two actions that could be executed at the same time (“mutually compatible”), whereas Experiment 3 used two actions that could not be executed at the same time (“mutually exclusive”). If motor simulation of different actions is bound by motor constraints, the same pattern should not be observed when the hands perform mutually exclusive actions.

2. Experiment 1

2.1. Participants

Experiments 1 and 2 aimed to test 50 participants, based on our previous research (Cracco & Brass, 2018a, 2018b). A sample of 50 participants provides us with 93% power to detect medium-sized effects of $d_z = 0.50$. However, due to cancellations, Experiment 1 comprised 48 individuals who were paid 5 euro in exchange for participation. Three participants with a reaction time (RT) or error rate (ER) exceeding the sample mean by more than 3 *SD* were excluded. The final sample thus consisted of 45 participants (36 female, $M_{age} = 23.67$, $SD_{age} = 5.16$). Participants in all experiments were right-handed, had normal or corrected-to-normal vision, and signed an informed consent before the start of the experiment.

2.2. Method

The experiment started with a practice phase of 12 trials, followed by an experimental phase of 240 trials divided into five blocks. Stimuli consisted of four hands abducting the index finger, abducting the little finger, or not moving (Fig. 1a). In the “THREE” condition, three hands moved the same finger and one hand did not move. In the “FOUR” condition, all four hands moved the same finger. Finally, in the “THREE-ONE” condition, three hands moved the same finger and one hand moved the other finger. The THREE and FOUR conditions both served as baseline conditions for the THREE-ONE condition. That is, the THREE condition matches the number of hands moving the same finger and the FOUR condition matches the total number of moving hands.

An illusion of motion was created by presenting a sequence of two pictures. That is, each trial started with a picture of the hands in their neutral position together with a fixation cross in the center of the screen. After 500 ms, this picture was replaced by a picture of the hands in their final position and a letter indicating the expected response. Participants had to abduct their right index finger when W was presented and their right little finger when P was presented. The actions performed by the stimulus hands could be congruent or incongruent with respect to the instructed response. Automatic imitation in this paradigm is a congruency effect with slower responses on incongruent trials than on congruent trials (Cracco et al., 2018). In the THREE-ONE condition, a trial was coded as congruent when the majority of the hands were congruent and as incongruent when the majority of the hands were incongruent. Participants had 2000 ms to respond following the presentation of the imperative cue. Responses were registered with an optical sensor box and were followed by a black screen for 1000 ms.

All trials of the Number (THREE, FOUR, or THREE-FOUR) × Congruency (congruent or incongruent) design were presented randomly with the restriction that the same cue could not appear more than four times in a row. The RT data was analyzed with a repeated measures MANOVA. Prior to analysis, we removed trials without a response (0.10%), trials with an RT faster than 100 ms (0.02%), error trials (3.98%), and trials with an RT deviating more than 3 *SD* from the participant’s mean (1.35%). The ER data is reported in Supplementary material (Fig. S1). There was no sign of a speed-accuracy trade-off. The stimuli, code, data, and analyses from all experiments are available on the Open Science Framework: https://osf.io/8xpc2/.

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.cognition.2018.07.007.

2.3. Results and discussion

The results revealed a main effect of congruency, $F(1, 44) = 56.07$, $p < .001$, $\eta_p^2 = 0.56$, with faster RTs on congruent trials than on incongruent trials, but no main effect of number, $F(2, 43) = 0.30$, $p = .741$, $\eta_p^2 = 0.01$. As predicted, there was a number × congruency interaction, $F(2, 43) = 3.47$, $p = .040$, $\eta_p^2 = 0.14$. Planned comparisons showed that the congruency effect was smaller in the THREE-ONE condition than in the THREE, $t(44) = -2.10$, $p = .041$, $d_z = 0.31$, and FOUR conditions, $t(44) = -2.56$, $p = .014$, $d_z = 0.38$. However, there was no significant difference between the congruency effect in the THREE and FOUR conditions, $t(44) = -0.65$, $p = .520$, $d_z = 0.10$ (Fig. 2).

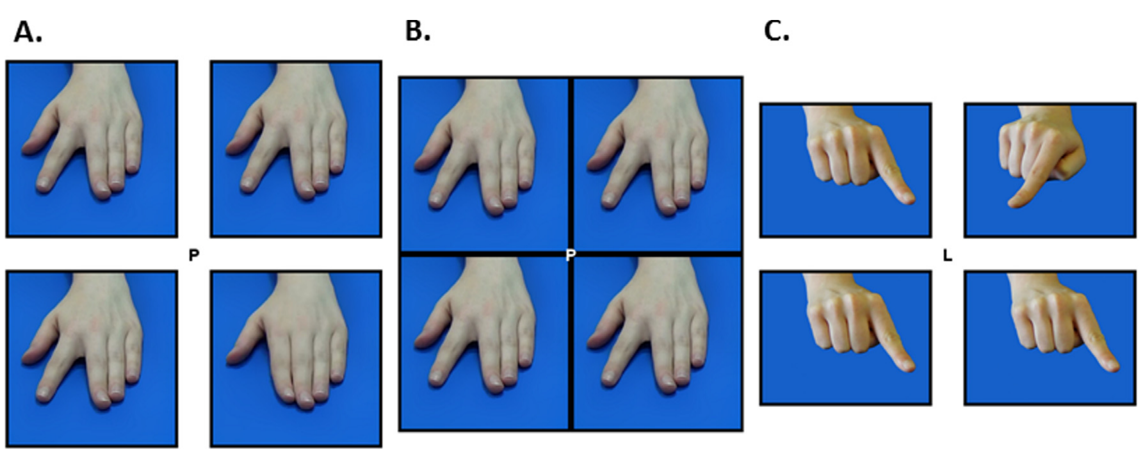

Fig. 1. Examples of the stimuli used in (a) Experiment 1, (b) Experiment 2, and (c) Experiment 3. In all three experiments, participants had to respond to the letter while three or four hands performed a congruent or incongruent action. In the THREE condition, three hands performed the same action and one hand did not move (panel A). In the FOUR condition, all four hands performed the same action (panel B). In the THREE-ONE condition, three hands performed the same action and one hand performed a different action (panel C).

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