



HAL
open science

Regulation of automatic imitation: domain-specific vs. domain-general control processes

Cédric A. Bouquet, Robrecht P.R.D. Van Der Wel, Mélissa Lafleur, Sean Duffy

► To cite this version:

Cédric A. Bouquet, Robrecht P.R.D. Van Der Wel, Mélissa Lafleur, Sean Duffy. Regulation of automatic imitation: domain-specific vs. domain-general control processes. *Journal of Experimental Psychology. Human Perception and Performance*, In press, 10.1037/xhp0001282 . hal-04811186

HAL Id: hal-04811186

<https://hal.science/hal-04811186v1>

Submitted on 29 Nov 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

©American Psychological Association, 2024. This paper is not the copy of record and may not exactly replicate the authoritative document published in the APA journal.

The final article is available, upon publication, at: [10.1037/xhp0001282](https://doi.org/10.1037/xhp0001282)

Peer Review Version

Regulation of automatic imitation: domain-specific vs. domain-general control processes

Cédric A. Bouquet^{1,2}

Robrecht P.R.D. Van Der Wel³

Mélissa Lafleur¹

Sean Duffy³

¹ University of Poitiers, CNRS, CeRCA, Poitiers, France

² Université Clermont-Auvergne, CNRS, LAPSCO, Clermont-Ferrand, France

³ Department of Psychology, Rutgers University, Camden, NJ

Word count: 12869

Author Note

Cedric A. Bouquet  <https://orcid.org/0000-0003-4228-3291>

Data and stimuli are openly available at the project's Open Science Framework page (<https://osf.io/vtbxj>). We have no conflicts of interest to disclose.

Correspondence concerning this article should be addressed to C.A. Bouquet, Université Clermont Auvergne, LAPSCO, 17 Rue Paul Collomp, F-63000 Clermont-Ferrand - France.

Email: cedric.bouquet@uca.fr

Abstract

The tendency to automatically imitate others' behavior is well documented. Successful interactions with others require some control of automatic imitation, but the nature of these control mechanisms remains unclear. The present study investigated whether the regulation of automatic imitation involves domain-specific vs. domain-general control processes. Automatic imitation was assessed using the imitation-inhibition task, in which participants responded to an imperative stimulus with finger movements while seeing imitatively congruent vs. incongruent, task-irrelevant movements. In Experiment 1, the imitatively congruent/incongruent trials ratio was manipulated and increasing the amount of incongruent trials reduced the imitative congruency effect – as typically observed in 'non-social' conflict tasks. In Experiment 2a, the imitation-inhibition task was intermixed with the Simon (spatial congruency) task. The ratio of spatially congruent/incongruent trials in the Simon task was varied while keeping the ratio of imitatively congruent/incongruent trials constant. Results indicate that increasing the amount of Simon conflict reduced both Simon and imitative congruency effects. Thus, control adaptations related to Simon congruency transferred to automatic imitation. In Experiment 2b and 3, the manipulation of the proportion of incongruent trials in the imitation-inhibition task did not exert an influence on the Simon effect. We discuss the domain-specific vs. domain-general nature of the mechanisms regulating imitation in the light of these conflicting findings.

Keywords: automatic imitation; imitation control; self-other distinction; social cognition

Public significance statement

The processes examined here are associated with almost all situations in which humans interact face to face. The present research focuses on the automatic tendency of individuals to imitate others. Cognitive mechanisms are required to regulate automatic imitation for successful interactions with others. We report results showing that the regulation of automatic imitative tendencies can be contextually adapted. Our study also shows that experiencing non-imitative conflict can influence automatic imitation, but not vice versa, providing new insight on the domain-general vs. domain-specific nature of the mechanisms involved in the regulation of imitation.

Peer Review Version

Regulation of automatic imitation: domain-specific vs. domain-general control processes

There is ample evidence that we tend to automatically imitate others' behavior, including postures, facial expressions, characteristics of language, and simple gestures such as hand or finger movements (Duffy & Chartrand, 2015; Heyes, 2011). Automatic imitation and its underlying mechanisms are thought to play a critical role in social cognition (Duffy & Chartrand, 2015; Iacoboni, 2009). However, for successful interaction with others and in order to pursue our own goals in the presence of other acting agents, it is necessary to regulate automatic imitation. Characterizing the control processes that regulate the tendency to copy others' behaviors is thus of particular importance for our understanding of the mechanisms that allow people to navigate the social world. A critical question is whether automatic imitation is regulated by specialized or domain-general processes. The present study aimed to further our knowledge on the specificity of the regulation of automatic imitation by examining the influence of the degree and nature of conflict experienced during an imitation-inhibition task.

The origin of the tendency to copy others' actions has been the focus of considerable theoretical and empirical work. Automatic imitation is typically assumed to occur because the perceived action triggers a corresponding motor representation in the observer (Brass & Heyes, 2005; Heyes, 2011). Why does perceiving others' actions trigger motor representations in the observer? Current accounts of automatic imitation converge on the idea that the repetitive experience of executing and seeing one's own actions establishes associations between 'motor' representations (or motor codes) and 'sensory' (visual, auditory, ...) representations of action (Heyes, 2011; Hommel, 2019). Being imitated and synchronous action may also provide the sensorimotor experience that generates this kind of action-perception links (Heyes, 2011). Once these links are established, the visual representation of an action (executed by another individual) can trigger, in the observer, the motor representation it is associated with. At a neurophysiological level, this visuo-motor translation

is assumed to be implemented by the mirror neuron systems (Cook et al., 2014; Iacoboni, 2009).

The precise functions of such action-perception links remain debated (Heyes & Catmur, 2022; Keysers et al., 2018). There is however a general agreement that these links and their behavioral expression (automatic imitation) are involved in social cognition. For instance, it has been demonstrated that mimicry can foster positive attitudes towards the imitator in the mimicked individual (Chartrand & Bargh, 1999; Duffy & Chartrand, 2015). Conversely, imitating another individual increases liking of this person (Stel & Vonk, 2009). Furthermore, the action-perception links at the origin of automatic imitation are important for social learning in that they would also provide the basis for intentional imitation (Bunlon et al., 2015; Heyes, 2011). Also, research suggests that facial mimicry has a causal effect on emotion understanding (Wood et al., 2016). In the same vein, mirror neuron systems, which are tightly linked to automatic imitation, have been proposed to play a role in the understanding and/or anticipation of others' actions (Bonini et al., 2023).

Imitation-inhibition task

Spontaneous imitation has been well documented by research on behavioral mimicry during live social interactions. This research has shown that the production of a specific behavior by an interacting confederate increases the occurrence of this behavior in participants (Chartrand & Lakin, 2013; Duffy & Chartrand, 2015). Further evidence for an uncontrolled tendency to copy others' actions also comes from research based on Reaction Time (RT) measures of the inhibition of automatic imitation (Heyes, 2011). This approach rests on a special kind of stimulus-response compatibility effect induced via a procedure similar to that used in Stroop-like tasks. In the so-called imitation-inhibition task introduced by Brass et al. (2000), participants had to respond to an imperative cue (the number "1" or "2") by lifting their index or middle finger. Furthermore, the imperative cue was accompanied by the presentation of another person's hand lifting its index or middle finger. The results showed that both RT and error rate were smaller when the observed – task irrelevant – movement and the instructed

response matched (congruent trials) than when they did not match (incongruent trials). The fact that the observed action tends to be imitated regardless of whether it is beneficial or detrimental for response selection has been considered as evidence for uncontrolled, involuntary imitation (Heyes, 2011). The impaired performance on imitatively incongruent vs. congruent trials has been replicated in numerous studies using various versions of the imitation-inhibition paradigm and this effect has been widely used as an index of automatic imitation (for reviews, see Cracco et al., 2018; Heyes, 2011). Subsequently, we will use the terms *imitation interference* to refer to the impaired performance on imitatively incongruent trials as compared to congruent trials in the imitation-inhibition task. In what follows, we address the question of the specificity of the control processes involved in the regulation of automatic imitation.

Control of automatic imitation

Cognitive control allows the optimization of information processing in accordance with internal goals. More specifically, control processes enable the inhibition of the processing of irrelevant information, unwanted thoughts or dominant responses in favor of appropriate ones (Braver, 2012; Cohen, 2017). Despite its automatic nature (Catmur, 2016; Heyes, 2011; Ramsey et al., 2019), spontaneous imitation seems to be under the influence of control processes. First, it is obvious that, fortunately, we do not overtly imitate others all the time. This suggests that we are able to exert some control on our tendency to copy others' actions, at least to prevent the systematic reproduction of observed behaviors. In line with this, research has shown that behavioral mimicry is modulated by social variables (Chartrand & Lakin, 2013). For instance, the tendency to adopt the same posture as another individual is increased for ingroup vs. outgroup members or following social exclusion (Cheng & Chartrand, 2003; Lakin et al., 2008). Finally, in the imitation-inhibition paradigm, participants succeed in responding correctly in the vast majority of trials. Thus, it is assumed that individuals are able to produce the required response in the face of an incongruent movement thanks to processes that allow to solve the conflict between internally generated and externally activated action representations (Cracco

et al., 2018; Ramsey, 2018). In other words, control processes are recruited to suppress the observed (incongruent) action and prioritize the self-generated, to-be-produced action.

Although there is evidence for representations of others' bodies or actions in dedicated networks (e.g. mirror neuron systems), the specificity of the control processes operating on these representations is less clear (Ramsey, 2018; Ramsey & Ward, 2020). Hence, a question that is currently debated is whether the regulation of automatic imitation (hereafter referred to as *imitation control*) relies on domain-general or domain-specific control processes. Processes that are domain-general apply to different types of stimuli and tasks (e.g., social and non-social, verbal and non-verbal), while domain-specific processes are held to apply to specific tasks or a stimulus category (Barrett, 2012). In the present context, domain-specific processes would refer to processes that are specifically engaged in imitation control or – more broadly – dedicated to social interactions and stimuli. Thus, elucidating the specificity of imitation control is important as it relates to the larger question of the specificity of the processes involved in social vs. non-social cognition (Heyes, 2014; Ramsey & Ward, 2020; Spunt & Adolphs, 2017).

In the context of the imitation-inhibition task, the question about the specificity of imitation control can be posed in these terms: are the processes recruited to overcome imitation interference identical or different from the (domain-general) control processes recruited to deal with interference in 'non-social' conflict tasks such as the Stroop and the Simon tasks? Indeed, the imitation-inhibition task can be seen as a variant of typical conflict tasks. The principle of conflict tasks is to have participants negotiate interference from task-irrelevant information that signals a response conflicting with the (correct) response signaled by task-relevant information. In the Stroop color-naming task, interference comes from the written word when it conflicts with the ink color of the word; in the Simon task, interference comes from the location of the stimulus when it conflicts with the location of the correct response. Research indicates that conflict generated in these tasks recruits domain-general processes of control (Cieslik et al., 2015; Fedorenko et al., 2013; Wager et al., 2005). The imitation-inhibition task is a special kind of conflict task where interference comes from a social stimulus (i.e. a stimulus representing another individual's action). Therefore, one might ask

whether imitation control, as indexed in the imitation-inhibition task, relies on specialized processes or on the same domain-general processes as those involved in 'non-social' Stroop-like tasks.

So far, theorizing about the nature of imitation control has been particularly fueled by results from neuroimaging and neurostimulation research on the neural correlates of the interference effect in the imitation-inhibition task. Thus, we first give an overview of this line of research, although the present work consists of a behavioral approach to imitation control. Then, we describe some behavioral studies that have addressed the question of imitation control.

Neuroimaging studies have reported the engagement of the right temporo-parietal junction (rTPJ) and the medial prefrontal cortex (mPFC) in imitation control (Brass et al., 2001,2005; Wang et al., 2011). Consistent with these findings, disrupting and enhancing activity of the rTPJ by transcranial magnetic stimulation respectively increases and reduces interference effects in the imitation-inhibition task (Hogeveen et al., 2015; Sowden & Catmur, 2015). Sowden and Catmur (2015) measured imitative and spatial (non-social) compatibility effects simultaneously. They found that neurostimulation of the TPJ modulated imitative compatibility effects but not spatial compatibility effects, suggesting a specific role of the TPJ in the regulation of imitation. Importantly, the TPJ and mPFC are assumed to be part of a specialized network supporting various social-cognitive functions, including empathy and theory of mind (Marsh, 2018; Schurz et al., 2014). More specifically, these two regions have consistently been found to be implicated in situations requiring the distinction between self- and other-related representations, as in visual perspective taking and false-beliefs tasks (for reviews, see Bukowski, 2018; Quesque & Brass, 2019). On this basis, it has been proposed that imitation control relies on a domain-specific process of self-other distinction, supported especially by the TPJ (Brass et al., 2009; Quesque & Brass, 2019; Sowden & Shah, 2014; Wang & Hamilton, 2012). According to this account, imitation control relies on a socially dedicated process that discriminates between self-related and other-related action representations. However, the evidence from fMRI and neurostimulation studies in favor of a

“specialized account” of imitation control has recently been questioned (Darda et al., 2018; Darda & Ramsey, 2019; Ramsey, 2018). First, a potential problem has been raised (Ramsey, 2018) concerning the argument that the engagement of TPJ and mPFC in imitation control reflects social processes. Indeed, the precise roles of these regions remain to be fully understood. For instance, the TPJ has also been related to more domain-general functions such as reorienting of attention by salient stimuli (Corbetta & Shulman, 2002; Dugué et al., 2018; Mitchell, 2008) and adjustment of expectations based on new sensory information (Geng & Vossel, 2013). Second, some studies have found no engagement of TPJ or mPFC in the control of imitation and instead reported activations in dorsal prefrontal and parietal cortices (Crescentini et al., 2011; Darda et al., 2018; Mengotti et al., 2012). Ramsey (2018) argued that these regions are part of the domain-general control (or multiple demand) network, which is recruited in various conflict tasks, including Stroop, flanker and Simon tasks (Bunge et al., 2002; Duncan, 2010; Wager et al., 2005 ; but see Sowden & Catmur, 2015). Finally, a recent meta-analysis of fMRI studies on the control of automatic imitation confirmed the engagement of the domain-general control network, while showing only weak evidence for the recruitment of TPJ and mPFC (Darda & Ramsey, 2019). Thus, current findings from neuroimaging and neurostimulation studies are ambiguous regarding the specificity of the processes supporting imitation control.

At the behavioral level, training to inhibit imitative responses (via performing a variant of the imitation-inhibition task) has been shown to improve subsequent visual perspective taking abilities (Santesteban et al., 2012; but see Bukowski et al., 2021). Such transfer is in line with the specialized account of imitation control: the recruitment of self-other distinction processes during the imitation-inhibition task promotes subsequent visual perspective taking that requires similar processes (setting aside one’s own perspective to adopt the other’s perspective). However, a non-social form of imitation control is also compatible with this kind of transfer since visual perspective taking would also rely on general processes of inhibition and attention (Heyes, 2014; Qureshi et al., 2020). Finally, it is worth considering a recent study that has investigated, in the context of the imitation-inhibition task, the modulation of imitation

interference by the proportion of congruent (observed and executed actions are similar) and incongruent (observed and executed actions are different) trials (Gordon et al., 2020). In this study, participants performed blocks of trials that contained either mostly (i.e. 75 %) congruent trials (MC condition) or mostly (75%) incongruent trials (MI condition). Individuals with autism spectrum disorder and individuals with typical development were tested. In both groups, the amplitude of imitation interference was substantially reduced in the MI condition as compared to the MC condition. The effect of the proportion of congruent to incongruent trials has been largely documented in typical conflict tasks like the Stroop and flanker tasks (for a review, see Bugg & Crump, 2012). A popular interpretation of this so-called “proportion congruency effect” is that it reflects cognitive control adjustments (Botvinick et al., 2001). Basically, it is assumed that the frequent experience of conflict in the MI condition reinforces cognitive control (we will return to this interpretation below). Therefore, the finding of a proportion congruency effect in the imitation-inhibition task (Gordon et al., 2020) may be seen as the sign that domain-general processes underlie imitation control. However, one cannot exclude that specialized processes of self-other distinction also show a sensitivity to proportion congruency that mirrors what is observed for domain-general control processes. The above described transfer from imitation inhibition to visual perspective taking (Santiesteban et al., 2012) is compatible with this view (i.e. imitation control is reinforced during the practice of imitation inhibition and this subsequently improves visual perspective abilities).

In sum, whether imitation control involves domain-general or domain-specific processes remains debated. The aim of the present study was to contribute to this debate by building on the proportion congruency effect that has been demonstrated in conflict tasks. Below, we give more detail on this effect before presenting our approach to imitation control.

The present study

Several studies have shown in a variety of conflict tasks that the amplitude of the interference effect is smaller when incongruent trials are frequent than when they are rare (e.g. Bonnin et al., 2010; Kane & Engle, 2003). Several interpretations of this proportion congruency effect

have been proposed (for an overview of the different accounts, see Bugg, 2017). As mentioned above, one of the most influential accounts is that the effect is the expression of an adjustment in cognitive control settings. Accordingly, the frequent occurrence of conflict (incongruent trials) leads to the recruitment of a “pro-active” mode of control, which consists in anticipating conflict by enhancing attentional bias toward the relevant stimulus dimension and/or increasing inhibition of the irrelevant one (Botvinick, 2012; Botvinick et al., 2001; Bugg & Crump, 2012; Egner, 2014). For instance, in the Stroop color-naming task, the influence of the word is thus attenuated in the MI condition, as compared to the MC condition, resulting in a smaller Stroop/interference effect. Recent empirical work has provided evidence supporting the general cognitive control account vs. other interpretations of proportion congruency effects (Spinelli & Lupker, 2022a, 2022b). Although the debate is certainly not settled (we will return to this point in the general discussion), in the present study, we will embrace the control-based account of the proportion congruency effect.

An interesting finding (consistent with a control-based account of proportion congruency effect) is that manipulating the congruent/incongruent trials ratio for one set of stimuli can transfer to another set of unbiased stimuli (Bugg, 2014; Bugg et al., 2011). Most relevant for the present purpose, studies have demonstrated that proportion congruency manipulation in one task can transfer to another unbiased task (Torres-Quesada et al., 2013; Wühr et al., 2015; but see Bausenhart et al., 2021). More specifically, Wühr et al., (2015) intermixed trials in the Stroop and Simon tasks. They manipulated the proportion of congruent trials in one task (e.g. Stroop), while keeping the ratio between congruent and incongruent trials equal in the other, unbiased task (e.g. Simon). They found that increasing the proportion of congruent trials in the Stroop task increased not only the size of the Stroop effect, but also the size of the Simon effect, although the Simon task was unbiased in terms of proportion congruency (i.e. congruent to incongruent trial ratio = 50:50).

Now, turning back to the question of imitation control, we adopted the following reasoning to test its specificity. If imitation is regulated by the same domain-general control processes as those involved in non-social conflict tasks (Wager et al., 2005), one should be

able to observe a transfer of the proportion congruency effect between the imitation-inhibition task and a non-social conflict task, paralleling what has been observed, for instance, between the Simon and Stroop tasks (see above). Thus, in the present study, we used a paradigm combining the imitation-inhibition task and the Simon task. Participants responded to stimuli that, depending on the type of trial, could either induce a Simon effect or imitation interference. We manipulated the proportion of congruent Simon trials, while keeping the proportion of congruent and incongruent imitation trials equal (Experiment 2a), and vice-versa (Experiment 2b and 3). If the same control processes regulate both types of congruency effects (imitative and Simon), a manipulation of the proportion of congruent trials in Simon-like trials should affect not only the size of the Simon effect, but also the size of imitation interference. Likewise, manipulating proportion congruency in the imitation-inhibition trials should affect both imitation interference and Simon effect. Alternatively, if proportion congruency effects remain restricted to the biased task (i.e. no transfer effect), then this would argue for a specialized account of imitation control.

Before testing these hypotheses, we ran an experiment (Experiment 1) to replicate the proportion congruency effect in the context of the imitation-inhibition task (Gordon et al., 2020). As explained above, the demonstration of such an effect does not allow to disambiguate the nature of imitation control. Nonetheless, one can still argue that if automatic imitation is regulated by mechanisms that are the same or similar to those involved in the regulation of interference from non-social stimuli, imitation interference should be sensitive to the congruent to incongruent ratio. Most importantly, in order to test for transfer of proportion congruency effects it is necessary to ascertain that we can obtain a modulation of imitation interference by the proportion of imitatively congruent and imitatively incongruent trials in the imitation-inhibition task.

Experiment 1

The aim of Experiment 1 was to test whether, in the imitation-inhibition task, a condition with high vs. low proportion of congruent trials respectively increases and decreases the size of

the imitation interference effect relative to a control condition with an equal number of congruent and incongruent trials.

Method

Transparency and openness

Data and hand stimuli are publicly accessible at the Open Science Framework (<https://osf.io/vtbxi/>). We report all data exclusions in the study. Data were analyzed using JASP 0.16.3 (JASP Team, 2020). Power analyses were conducted using MorePower 6.0.4 (Campbell & Thompson, 2012). This study was not preregistered.

Participants

In the first half of 2019, thirty-two undergraduates (21 females, 11 males; $M_{\text{age}} = 21.41$ years; $SD_{\text{age}} = 4.68$) from Rutgers University took part in Experiment 1 in exchange for course credit. The Rutgers subject pool is approximately 20% black, 20% white non-hispanic, 20% white hispanic, 20% other (asian and pacific), and 20% do not indicate an ethnicity. All were right handed, had normal or corrected-to-normal vision and were naïve with respect to the purpose of the experiment. The recruitment of right-handed participants was justified by the experimental set-up. Generalizability may therefore be limited to this specific population (right-handed and young adults).

Each participant read and signed an informed consent form prior to taking part in the experiment. The project was approved by Rutgers IRB Protocol # Pro2019002031. All experiments were performed in compliance with local laws and in accordance with the ethical standards set out in the 1964 Declaration of Helsinki.

A sensitivity analysis, conducted using MorePower 6.0.4 (Campbell & Thompson, 2012), indicated that for a 2 x 3 repeated measures ANOVA, with a sample size of $N = 32$, an alpha level of .05 and a power of .80, the minimum detectable effect size for the 2 x 3 interaction was $\eta^2_p = .140$ (Cohen's $f = .404$). This effect size is within the range of effect sizes reported in previous studies showing a proportion congruency effect (e.g. Bugg, 2014, $\eta^2_p = .190$; Wühr et al., 2015, $\eta^2_p = .71$)

Apparatus and Material

The presentation of stimuli and the registration of manual responses were controlled by E-prime software (version 2.0, <http://www.pstnet.com>). Stimuli were presented on a 20-in. monitor.

Participants were seated approximately 50 cm from the screen, with their index and little fingers of the right hand resting on two keys of a response device (a customized keyboard) placed in front of them. The two response keys were separated by approximately 9 cm and they were arranged so that when a participant rested his/her hand on the response device, the index and little fingers held down the left and right key, respectively.

During the experiment, participants observed a right hand lifting its index or little finger. The hand was presented, as viewed from above, in color on a black background in the middle of the screen. It occupied approximately 7.6° of visual angle horizontally and 13.3° vertically, and it was oriented in the horizontal axis, that is, orthogonal to the participant's hand, to minimize spatial-compatibility effects (Cracco et al., 2018; Jiménez et al., 2012). Finger lifting movement was produced by presenting a picture of the hand in a resting (neutral) position followed by a picture of the same hand with the index or little finger lifted and slightly abducted. The replacement of the initial image by the final finger position produced an apparent finger movement. The finger movements subtended an angle of 2.6° (index) and 2.2° (little) from the neutral position.

Design and procedure

Instructions were displayed on the monitor and paraphrased by the experimenter. Participants were asked to respond to a cue (a blue or orange dot) by lifting their index or little finger of their right hand, while ignoring congruent or incongruent movements simultaneously shown on the screen (Figure 1A). Half of participants were instructed to lift their little finger when the blue dot was presented and lift their index finger when the orange dot was displayed. This stimulus-response mapping was reversed for the other half. Participants were instructed to respond as fast as possible while avoiding mistakes.

Each trial began with the picture of the hand in neutral position, presented for 800 or 1200 ms. For compatible and incompatible trials, this picture was then replaced by a picture of the same hand with its index or little finger lifted. After a 70-ms delay (Catmur & Heyes, 2011), the imperative stimulus (a blue or orange dot, 1 cm diameter) was superimposed on the hand picture, between the 3rd and 4th finger (Figure 1B). The outline of a white circle indicated the location of the colored circle. For neutral trials, the image of the neutral hand remained unchanged before presentation of the imperative stimulus. These stimuli remained on the screen until a response was given or after 1500 ms elapsed. The next trial started after a 750-ms blank interval, during which the message "Error" was displayed in case of an error (wrong response) or omission. During this interval, the participant had to place his/her lifted finger back on the response key.

There were three types of trials. In congruent trials, the response required to the imperative stimulus was similar to the finger movement displayed on the screen. In incongruent trials, the instructed response was different from the movement displayed on the screen. In neutral trials, the imperative stimulus was not accompanied by the display of finger movement. The motivation for the use of neutral stimuli was first to increase the number of possible stimuli. Second, performance on neutral trials allowed us to check whether the RT to the imperative stimulus, in the absence of any irrelevant movement stimulus, was comparable in the different proportion conditions. Therefore, neutral trials were not included in the main analyses and analyzed separately.

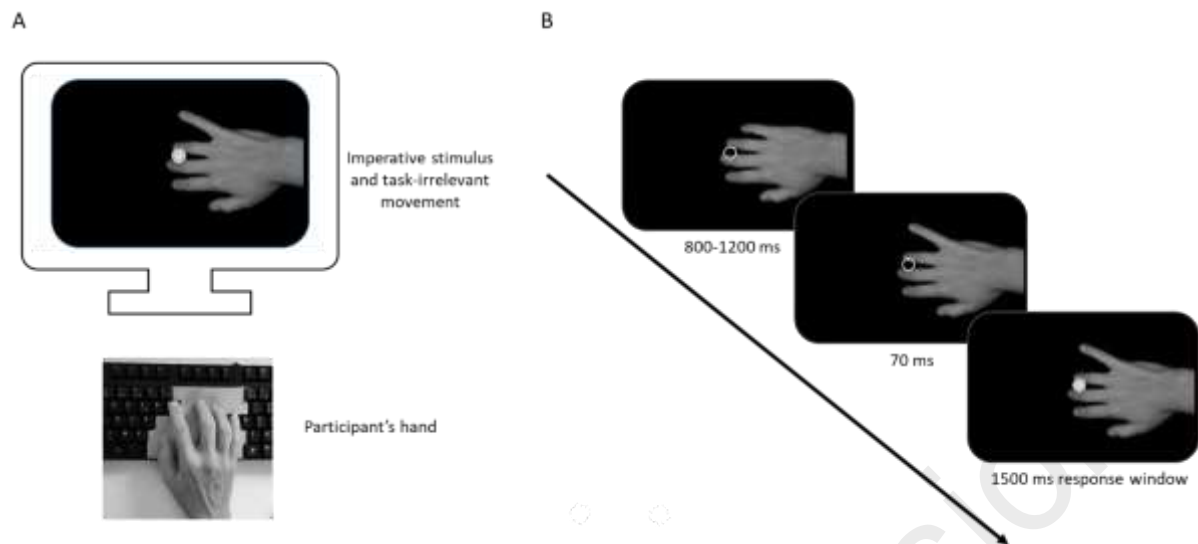


Figure 1. (A) Schematic description of the experimental set-up. Participants had their hand resting on a customized keyboard. The imperative stimulus (a blue or orange dot) was displayed on a screen along with a hand producing finger movements. (B) Trial sequence.

After 28 practice trials (which consisted of 10 congruent, 10 incongruent and 8 neutral trials), participants performed experimental blocks of trials in different conditions that varied in terms of proportion congruency: mostly congruent (MC), mostly incongruent (MI), and control (CTRL) conditions. Each MC/MI/CTRL condition consisted in two consecutive sub-blocks of 48 trials. In the MC condition, each sub-block contained 24 (50%) congruent trials, 8 (17%) incongruent trials, and 16 (33%) neutral trials. In the MI condition, each block contained 8 congruent trials, 24 incongruent trials, and 16 neutral trials. In the CTRL condition, there were 16 trials of each type (congruent, incongruent, and neutral) per block. The imperative stimulus and the movement displayed were selected pseudo-randomly so that the desired congruency proportions were obtained and so that for a given type of trial (congruent, neutral and incongruent), each dot-movement stimulus combination occurred the same number of times. Each block of trials was followed by a short break (30-60 sec). The order of the congruency proportion conditions was counterbalanced between participants.

The experiment had a 2 (Imitative congruency) by 3 (Proportion) within-subjects design.

Data analysis

Because the manipulated factors (proportion and imitative congruency) can have an influence on both RTs and error rates (ER), we computed for each participant and in each condition, a linear integrated speed-accuracy score (LISAS) to integrate speed and accuracy (Vandierendonck, 2017, 2021). For subject i in condition j , LISAS is computed as $\text{Mean_RT}_{ij} + (\text{SD_RT}_i / \text{SD_ER}_i) \times \text{Mean_ER}_{ij}$. The LISAS is thus a RT corrected for error rate. The use of LISAS is recommended in conflict tasks such as the imitation-inhibition task where a potential tradeoff between speed and accuracy can occur (Vandierendonck, 2017, 2021). We thus focused on the analysis of LISAS¹. Analyses of mean RTs, error rates and another integrated score (inverse efficiency score) are provided in the Supplementary materials.

As estimates of effect size, we report η_p^2 for ANOVAs. For t-tests, we report η_p^2 as well as Cohen's d .

Results and discussion

Trials in which no response was given before the 1500 ms time limit (0.84 %) were removed from all analyses. Additionally, trials with a RT faster than 100 ms (0.38%), were considered as action slip and excluded as well. Prior to calculation of mean RTs, we excluded erroneous trials (5.55 %) and then, for each participant and each condition, trials departing more than 2.5 standard-deviation from the mean RT (2.68 %).

The mean LISAS, RTs, and Error rates of Experiment 1 are shown in Table 1. LISAS were submitted to an ANOVA with Congruency (Congruent vs. Incongruent) and Proportion (MC, MI, CTRL) as within-participant factors. This analysis revealed a main effect of

¹ The way SD is calculated in the computation of LISAS (i.e. SD of the overall RT or error rate) can occasionally lead this score to be a function of RT variability, in that the difference between participants with equal RT and Error rate would then depend only on RT variability. This could be problematic when the study design involves between-participants factors. However, this is not the case when comparing different conditions of the same participant. For a given participant, all LISAS obtained in the different conditions are computed with the same SDs (i.e. the participant's overall RT standard deviation and the participant's overall ER standard deviation). As we used full within-participant designs in our study, this potential problem with LISAS did not affect our results. Importantly, we have conducted analyses of another integrated score (Inverse Efficiency Score - IES) which yielded the same results as those conducted on LISAS. The analyses of IES are reported in Supplementary materials, along with analyses of RTs and ER.

congruency, $F(1, 31) = 79.98$, $p < .001$, $\eta^2_p = .721$, with better performance on congruent trials ($M = 473$ ms, $SE = 13.789$) than incongruent trials ($M = 561$ ms, $SE = 17.071$). The main effect of Proportion was not significant, $F(2, 62) = 2.213$, $p = .118$, $\eta^2_p = .067$. Importantly, there was a significant interaction between Proportion and Congruency, $F(2, 62) = 14.049$, $p < .001$, $\eta^2_p = .312$. The amplitude of imitation interference ($\text{Incongruent}_{\text{LISAS}}$ minus $\text{Congruent}_{\text{LISAS}}$) was 79 ms, 95% CI [55, 102] in the CTRL condition, 139 ms, 95% CI [99, 119] in the MC condition, and 44 ms, 95% CI [28, 61] in the MI condition (Figure 2). To qualify the Proportion \times Congruency interaction, we used contrast coding with a focal contrast on the difference of congruency effect between MI vs. MC conditions (a detailed description of this analysis can be found in the Supplementary materials). Two orthogonal contrasts were thus applied to the three levels (CTRL, MC, MI) of the Proportion variable. For the first contrast C1 (MC vs. MI), the contrast codes were: CTRL [0], MC [1], MI [-1]; for the second contrast C2 (CTRL vs. MC + MI), the contrast codes were: CTRL [2], MC [-1], MI [-1]. The C1 \times Congruency interaction was significant, $t(31) = 4.465$, $p < .001$, $d = 0.789$, $\eta^2_p = .391$, whereas the C2 \times Congruency was not significant, $t(31) = -1.048$, $p = 0.303$, $d = 0.054$, $\eta^2_p = .003$. This shows that the imitative congruency effect was significantly smaller in the MI condition, as compared to the MC condition (Figure 2).

A one way ANOVA conducted on the neutral trials with the within-participant factor Proportion revealed no significant effect, $F(2, 62) = .674$, $p = .513$, $\eta^2_p = .021$ (CTRL: $M = 508$ ms, $SE = 17$; MC: $M = 496$ ms, $SE = 16$; MI: $M = 499$ ms, $SE = 18$).

Table 1. Means \pm Standard Errors of the Response Times (ms), Error Rates, and linear integrated speed-accuracy scores (ms) in Experiment 1.

Proportion	Congruency								
	Congruent			Incongruent			Neutral		
	LISAS	RT	ER	LISAS	RT	ER	LISAS	RT	ER
Mostly congruent	459 \pm 13	443 \pm 13	0.03 \pm 0.01	598 \pm 23	530 \pm 17	0.14 \pm 0.02	496 \pm 16	473 \pm 14	0.04 \pm 0.01
Control	472 \pm 15	452 \pm 14	0.04 \pm 0.01	552 \pm 18	512 \pm 16	0.08 \pm 0.01	509 \pm 17	488 \pm 16	0.04 \pm 0.01
Mostly Incongruent	489 \pm 17	468 \pm 17	0.05 \pm 0.01	534 \pm 17	503 \pm 18	0.08 \pm 0.01	499 \pm 18	485 \pm 18	0.03 \pm 0.01

Note. LISAS = Linear Integrated Speed-accuracy Score, RT = Response Time, ER = Error Rate

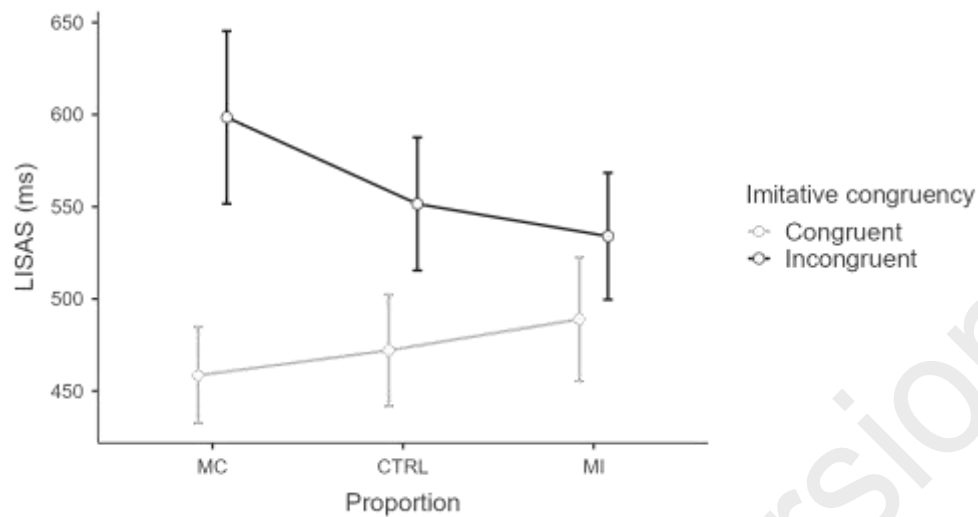


Figure 2. Means of LISAS in Experiment 1, as a function of imitative congruency and proportion of congruent and incongruent trials (CTRL = Control condition with a 50/50 congruent to incongruent ratio, MC = Mostly congruent condition, MI = Mostly incongruent condition). Error bars represent 95% CI.

Thus, Experiment 1 revealed that the proportion of congruent and incongruent trials within a block influenced the degree of imitation interference in the imitation-inhibition task. Paralleling what has been widely demonstrated in typical conflict tasks like the Stroop and Simon tasks (Bugg, 2017; Kane & Engle, 2003; Wühr et al., 2015), an increase in the frequency of imitatively congruent trials was associated with a larger imitation effect. A previous study reported a similar finding in the imitation-inhibition task (Gordon et al., 2020). In this previous research, the authors only contrasted a MI condition and a MC condition, which makes it impossible to determine whether this is the increase or the decrease in the proportion of congruent trials, or both, that affects imitation interference. Here, the inclusion of the control (CTRL) condition, with an equal number of congruent and incongruent trials, allowed us to answer this question, and the answer is 'both'. As compared to the CTRL condition, when the proportion of congruent trials was increased, imitation interference was augmented, while when the proportion of congruent trials was decreased, imitation interference was reduced.

Moreover, the inclusion of neutral trials, in terms of imitative congruency, allows us to speculate about the origin of the influence of proportion congruency on performance in the imitation-inhibition task. First, the fact that we observed no variation in performance on neutral trials across conditions suggests that the effect of proportion congruency was not related to a global modification of cognitive performance. Furthermore, proportion congruency can affect the processing of both task-relevant and task-irrelevant information (Bugg, 2017). Our findings suggest that, in the context of our imitation-inhibition task, the effect of proportion congruency cannot be reduced to a mere negative or positive influence on the processing of the imperative stimulus. If this was the case, one would expect performance on neutral trials to be affected by proportion congruency, but this is not what we observed. One may thus suggest that the manipulation of proportion congruency mainly impacted the ability to deal with the task-irrelevant movement stimuli.

Experiment 1 showed that automatic imitation, as indexed in the imitation-inhibition task, is sensitive to the proportion of congruent and incongruent trials. From there, we can move to the main goal of the study: investigating the transfer of proportion congruency effect between the imitation-inhibition task and a non-social conflict task.

In Experiments 2a and 2b, we tested whether the proportion congruency effect would transfer between the Simon and imitation-inhibition tasks. The rationale was that if the regulation of imitation involves domain-general control processes, proportion congruency effects obtained in the Simon task should transfer to the imitation-inhibition task and vice-versa. In Experiment 2a, the proportion of spatially congruent vs. incongruent trials in the Simon task was manipulated, while the proportions of imitatively congruent and incongruent trials in the imitation-inhibition task were equal. Conversely, in Experiment 2b, we manipulated proportion congruency in the imitation-inhibition task while keeping equal the amount of congruent and incongruent trials in the Simon task.

Experiment 2a

In this experiment, the imitation-inhibition task was intermixed with a Simon task. The procedure was modified by introducing a variation in the horizontal position of the imperative stimulus. By doing so, we set the conditions for the occurrence of a standard Simon effect based on the (mis)alignment of the locations of the imperative stimulus and responses along the left-right dimension.

We chose the Simon task because it allowed us to keep the target stimulus, S-R rules, and response modalities constant across the Simon and imitation-inhibition trials. Also, the introduction of Simon task trials was possible without major modifications of the typical imitation-inhibition task. Thus, even though we will refer here to two different tasks for convenience, there was no change of task-rule throughout the experiment. This aspect of the protocol was important because a change in response modality or of the relevant task-dimension seem to prevent the transfer of proportion congruency effects, even if the tasks are supposed to involve the same type of control processes (Braem et al., 2011; Funes et al., 2010; Torres-Quesada et al., 2013; Wühr et al., 2015).

Method

Participants

Forty-four undergraduates (31 females, 13 males; $M_{\text{age}} = 21.27$ years; $SD_{\text{age}} = 5.17$) from the University of Poitiers were recruited between May and December 2022 to participate in Experiment 2a in exchange for course credit. All were right handed, had normal or corrected-to-normal vision and were naïve with respect to the purpose of the experiment.

A sensitivity analysis indicated that for a $2 \times 2 \times 2$ repeated measures ANOVA, with a sample size of $N = 44$, an alpha level of .05 and a power of .80, the minimum detectable effect size for the $2 \times 2 \times 2$ interaction was $\eta^2_p = .160$ (Cohen's $f = .437$). In the study by Wühr et al. (2015) investigating the transfer of proportion congruency effects between tasks, the lowest effect size for the interaction between task, proportion and congruency was $\eta^2_p = .60$.

Material, design and procedure

The task was a variant of the task used in Experiment 1. The main change consisted of varying the location of the imperative stimulus on the horizontal axis: the colored dot could appear on the central location (i.e. as in Experiment 1) as well as 4 cm on the left or right side of the central location (Figure 3). The material and stimuli were the same as in Experiment 1, except that the possible locations of the imperative stimulus were indicated by the outline of three white circles.

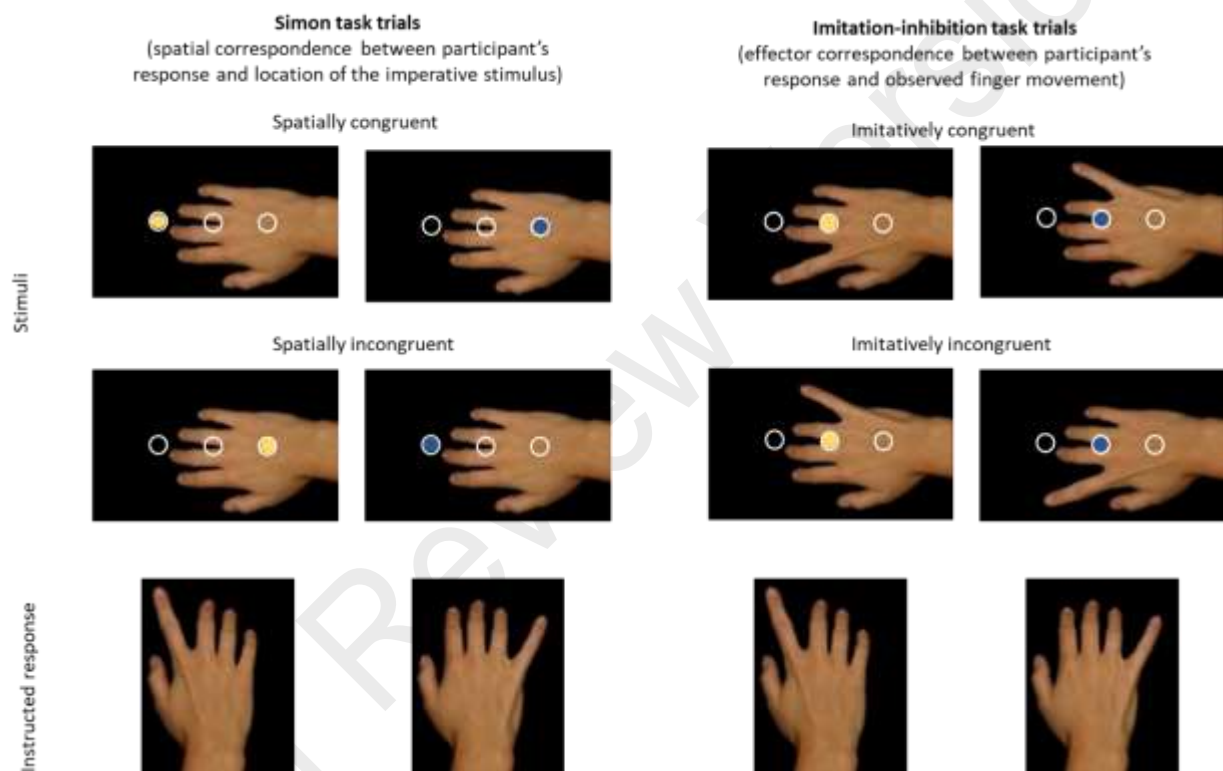


Figure 3. Trials in the Simon task (left) and Imitation-inhibition task (right). In the illustrated S-R mapping, participants responded to the orange stimulus by lifting their index finger and to the blue stimulus by lifting their little finger.

Imitation-inhibition task trials and Simon task trials were intermixed within a block. For trials in the imitation-inhibition task, the imperative stimulus was always presented in the central location (i.e. as in Experiment 1). This implies that for the imitation trials there was no manipulation of the alignment of response and stimulus location. For the Simon task trials, the

sequence of events was similar except that no finger movement was displayed and the imperative stimulus appeared either in the right or left side location. Thus, for trials in the Simon task, there was no manipulation of the imitative congruency.

In each block, there were 48 imitation-inhibition trials and 108 Simon trials (the larger amount of Simon trials was necessary to achieve the proportion congruency manipulation). In the MI condition, there were 36 congruent trials and 72 incongruent trials in the Simon task. These proportions were reversed in the MC condition. For the imitation-inhibition task, there were 24 congruent trials and 24 incongruent trials in both the MI and MC condition. Within a block of trials, the stimuli were selected pseudo-randomly so that the desired task and congruency proportions were obtained and so that for a given type of trial (congruent, incongruent) in a task, each combination of colored dot and movement or location occurred the same number of times. Participants performed one block of trials in each proportion condition (MI and MC). The order of blocks and the stimulus-response mapping were counterbalanced between participants. Before the experimental blocks, participants performed a practice block of 32 trials (with a ratio of congruent to incongruent trials of 50:50).

The experiment had a 2 (proportion) \times 2 (task) \times 2 (congruency) within-participants design.

Results and discussion

Of the 44 participants included in the experiment, data from one participant were excluded due to a recording error. The data from another participant who did not apply the correct S-R mapping (resulting in a near zero accuracy rate) were also excluded. As in Experiment 1, trials with no response (0.18 %) and with RT less than 100 ms (0.08 %) were excluded from all analyses. The outlier detection procedure applied to correct RTs resulted in the exclusion of 2.57 % of trials.

The results of Experiment 2a are presented in Table 2. We entered LISAS into a three factorial ANOVA with Proportion (MI vs. MC), Congruency (Congruent vs. Incongruent) and Task (Simon vs. Imitation) as within-participant factors. The analysis revealed a significant

main effect of Congruency, $F(1, 41) = 132.02$, $p < .001$, $\eta^2_p = .763$, and a significant main effect of Task, $F(1, 41) = 46.85$, $p < .001$, $\eta^2_p = .533$. The mean LISAS was 501 ms, 95% CI [484, 519] in the Simon task, and 477 ms, 95% CI [461, 493] in the Imitation task. There was a significant Task x Congruency interaction, $F(1, 41) = 252.83$, $p < .001$, $\eta^2_p = .860$, reflecting larger congruency effects in the Simon task (454 vs. 549) than in the Imitation task (470 vs. 484). The main effect of Proportion was not significant, $F(1, 41) = 0.051$, $p = .823$, $\eta^2_p = .001$. There was an interaction between Congruency and Proportion, $F(1, 41) = 40.59$, $p < .001$, $\eta^2_p = .497$, indicating a proportion congruency effect: the difference between incongruent and congruent trials, irrespective of the task, was reduced in the MI condition (33 ms) as compared to the MC condition (77 ms). Furthermore, the Proportion x Congruency x Task interaction was significant, $F(1, 41) = 13.04$, $p < .001$, $\eta^2_p = .241$, suggesting that the influence of proportion on the congruency effect was larger in the Simon task than in the Imitation task.

In the Simon task, the amplitude of the congruency effect was 128 ms, 95% CI [111, 145] in the MC condition, and it was reduced to 61 ms, 95% CI [51, 73] in the MI condition, $t(41) = 7.271$, $p < .001$, $d = 1.122$, $\eta^2_p = .563$ (Figure 4). For the Imitation task, the amplitude of the congruency effect/imitation interference was 25 ms, 95% CI [11, 38] in the MC condition, and it was 3 ms, 95% CI [-11, 17] in the MI condition, $t(41) = 2.341$, $p = .024$, $d = 0.361$, $\eta^2_p = .118$. Thus, the effect size of Proportion on Congruency was larger in the Simon task than in the Imitation task. But, in the Imitation task, the congruency effect was nonetheless significantly reduced in the MI condition as compared to the MC condition. One can further note that in the imitation task, in the MI condition, the 95% CI [-11, 17] of the imitative congruency effect included zero, indicating the effect was not significant.

Table 2. Means \pm Standard Errors of Response Times (ms), Error Rates, and linear integrated speed-accuracy scores (ms) in Experiment 2a.

Task	Proportion	Congruency					
		Congruent			Incongruent		
		LISAS	RT	ER	LISAS	RT	ER
Simon	Mostly congruent	439 \pm 7	435 \pm 7	0.01 \pm 0.00	568 \pm 12	521 \pm 9	0.09 \pm 0.01
	Mostly Incongruent	469 \pm 10	459 \pm 9	0.02 \pm 0.00	531 \pm 9	506 \pm 9	0.05 \pm 0.01
Imitation	Mostly congruent	464 \pm 9	454 \pm 8	0.02 \pm 0.01	489 \pm 10	471 \pm 10	0.04 \pm 0.01
	Mostly Incongruent	477 \pm 9	461 \pm 8	0.03 \pm 0.01	480 \pm 8	467 \pm 9	0.03 \pm 0.01

Note. LISAS = Linear Integrated Speed-accuracy Score, RT = Response Time, ER = Error Rate

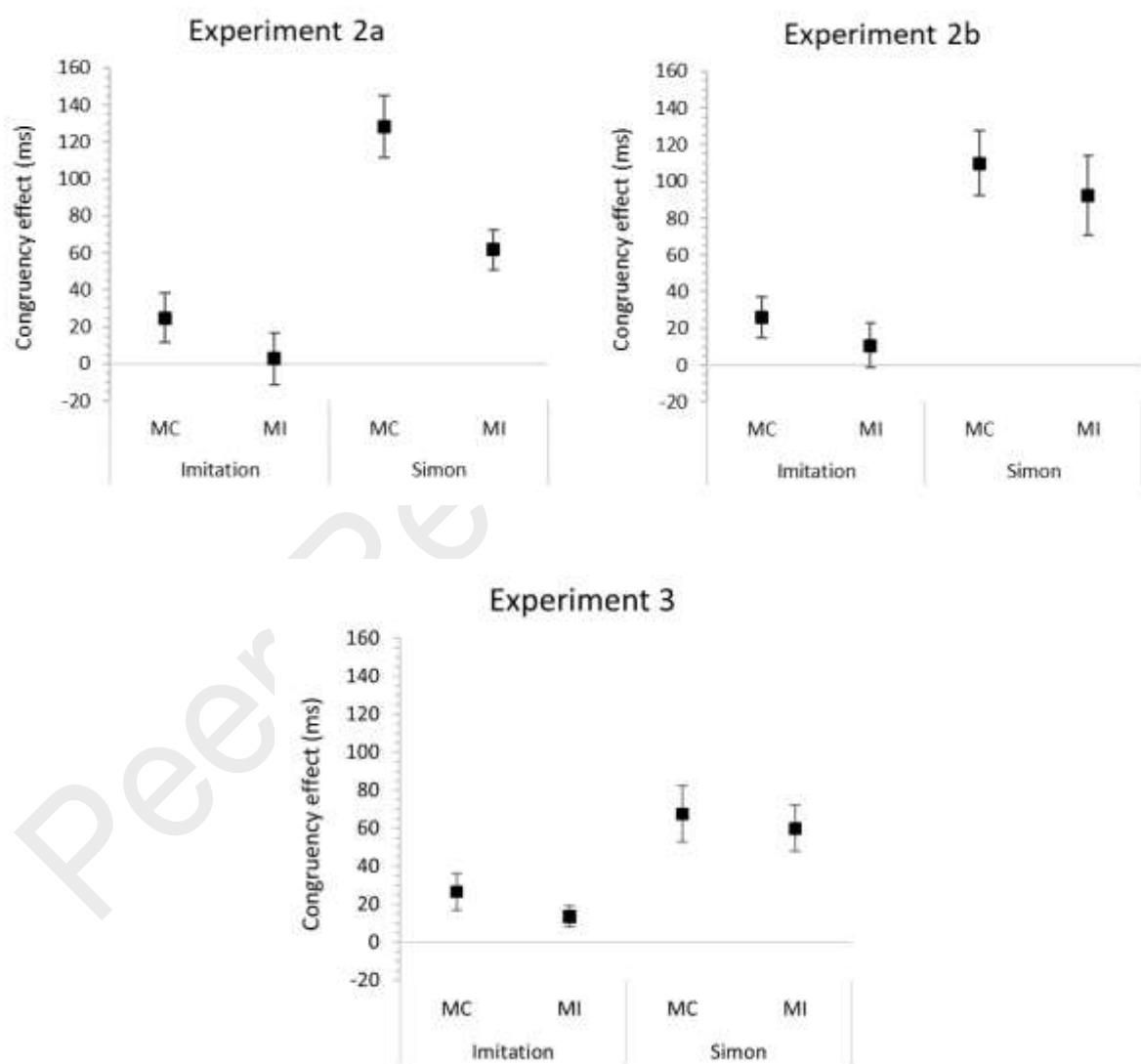


Figure 4. Congruency effect ($\text{Incongruent}_{\text{LISAS}}$ minus $\text{Congruent}_{\text{LISAS}}$) as a function of Proportion and Task, in Experiment 2a, Experiment 2b and Experiment 3. MC = Mostly congruent; MI = Mostly incongruent. Error bars represent 95% CI.

In line with previous work (Wühr et al., 2015), Experiment 2a showed that increasing the proportion of incongruent trials in the Simon task decreased the size of the corresponding Simon effect, i.e. the difference between incongruent and congruent trials was reduced in the MI condition as compared to the MC condition. Critically, this influence of proportion congruency was not restricted to the - biased - Simon task and extended to the - unbiased - imitation-inhibition task, in which imitation interference was also reduced in the MI condition relative to MC condition. There was thus a transfer of the proportion congruency effect from the Simon task to the imitation-inhibition task. In Experiment 2b, we tested whether transfer would operate the other way around, that is, whether a manipulation of proportion congruency in the imitation-inhibition task would transfer to the Simon task.

Experiment 2b

Method

Participants

The sample size was the same as in Experiment 2a. A total of 44 right-handed undergraduates (40 females, 4 males; $M_{\text{age}} = 18.97$ years; $SD_{\text{age}} = 4.33$) from the University of Poitiers were recruited between May and December 2022 and received course credit for their participation. All had normal or corrected-to-normal vision and were naïve with respect to the purpose of the experiment.

Material, design and procedure

The material and design were the same as in Experiment 2a. The difference was that in Experiment 2b, proportion congruency was manipulated in the imitation-inhibition task, while the amounts of congruent and incongruent trials were equal in the Simon task. In each block, there were 108 imitation-inhibition trials and 48 Simon trials. In the MI condition, there were 36 congruent trials and 72 incongruent trials in the imitation-inhibition task. These proportions were reversed in the MC condition. For the Simon task, there were 24 congruent trials and 24 incongruent trials in both the MI and MC condition.

Results and discussion

After exclusion of trials with no response (0.38 %) and with RT less than 100 ms (0.12 %), the outlier detection procedure applied to correct RTs resulted in the exclusion of 2.24 % of trials. The results of Experiment 2b are presented in Table 3.

An ANOVA was conducted on LISAS with Proportion (MI vs. MC), Congruency (Congruent vs. Incongruent) and Task (Simon vs. Imitation) as within-participant factors. The analysis revealed a significant main effect of Congruency, $F(1, 43) = 143.60$, $p < .001$, $\eta^2_p = .770$, and a significant main effect of Task, $F(1, 43) = 136.33$, $p < .001$, $\eta^2_p = .760$, with larger LISAS in the Simon task (538 ms, 95% CI [518, 558]) than in the Imitation task (490 ms, 95% CI [474, 507]). The Task x Congruency interaction was significant, $F(1, 43) = 87.11$, $p < .001$, $\eta^2_p = .670$, indicating larger congruency effects in the Simon task (488 vs. 589) than in the Imitation task (482 vs. 500). The main effect of Proportion was not significant, $F(1, 43) < .1$, $p = .862$, $\eta^2_p < .001$. There was an interaction between Congruency and Proportion, $F(1, 43) = 5.090$, $p = .029$, $\eta^2_p = .106$, indicating a proportion congruency effect. Thus, irrespective of the task, the difference between incongruent and congruent trials in the MI condition (51 ms) was significantly smaller than that measured in the MC condition (68 ms). Critically, the Proportion x Congruency x Task interaction was not significant, $F(1, 43) = 0.030$, $p = .863$, $\eta^2_p < .001$, suggesting that the influence of Proportion on the congruency effect did not vary depending on the task (Figure 4). Although the three-way interaction was not significant, we examined the congruency effect ($\text{Incongruent}_{\text{LISAS}} - \text{Congruent}_{\text{LISAS}}$) as a function of proportion in each task separately to get a clear picture of the results and parallel the analyses conducted on the results of Experiment 2a. In the Imitation task, the amplitude of the congruency effect was 26 ms, 95% CI [15, 37] in the MC condition and it was 11 ms, 95% CI [-2, 23] in the MI condition. Thus, the congruency effect was not significant in the MI condition (as indicated by 95% CI that includes zero), and it was smaller than in the MC condition, $t(43) = 2.052$, $p = .046$, $d = 0.309$, $\eta^2_p = .089$. In the Simon task, although the results tended to show a similar pattern, with a congruency effect of 110 ms, 95% CI [92, 127] in the MC condition and of 92 ms, 95% CI [71, 114] in the MI condition, the difference between the two conditions did not reach

significance, $t(43) = 1.512$, $p = .138$, $d = 0.228$, $\eta^2_p = .050$. To conclude about the absence of difference between the Simon effects in the MC and MI conditions, these congruency effects were compared with a Bayesian paired samples t -test with the default Cauchy prior (.707) (Morey et al., 2015), which indicated anecdotal evidence in favor of the null hypothesis, $BF_{01} = 1.723$.

Table 3. Means \pm Standard Errors of the Response Times (ms), Error Rates, and linear integrated speed-accuracy scores (ms) in Experiment 2b.

Task	Proportion	Congruency					
		Congruent			Incongruent		
		LISAS	RT	ER	LISAS	RT	ER
Simon	Mostly congruent	480 \pm 8	473 \pm 8	0.01 \pm 0.00	590 \pm 12	550 \pm 11	0.08 \pm 0.01
	Mostly Incongruent	496 \pm 12	487 \pm 10	0.02 \pm 0.01	588 \pm 13	551 \pm 11	0.07 \pm 0.01
Imitation	Mostly congruent	480 \pm 8	466 \pm 8	0.03 \pm 0.00	506 \pm 10	481 \pm 8	0.05 \pm 0.01
	Mostly Incongruent	483 \pm 9	467 \pm 8	0.03 \pm 0.01	494 \pm 10	474 \pm 9	0.04 \pm 0.01

Note. LISAS = Linear Integrated Speed-Accuracy Score, RT = Reaction Time, ER = Error Rate

In Experiment 2b, we found a significant influence of the proportion of imitatively congruent and imitatively incongruent trials on the size of congruency effects. This proportion congruency effect was not modulated by the factor Task - overall there was thus a reduction of the size of the congruency effect in the MI vs. MC condition. However, a separate analysis conducted in each task showed that the proportion-related reduction of the size of the congruency effect was significant in the Imitation-inhibition task, while it was not in the Simon task.

One can note that in Experiment 2b the proportion congruency effect was rather small as compared to Experiments 1 and 2a. As demonstrated in Experiment 2a, the proportion congruency in the Simon task can transfer to the imitation-inhibition task. Then, in both Experiment 2a and Experiment 2b, a significant Task x Congruency interaction showed that the congruency effect was larger in the Simon task than in the Imitation-inhibition task. Consequently, in Experiment 2b, it cannot be excluded that, although there were less Simon

task trials, the equal number of congruent and incongruent trials in this task partly counteracted the proportion manipulation that was implemented in the imitation-inhibition task.

Therefore, it might be necessary to strengthen the proportion manipulation in the imitation-inhibition task to observe a transfer toward the Simon task. This is what we tried to achieve in Experiment 3, by adapting the procedure used in Experiment 2b. In Experiment 3, we slightly increased both the number of trials and proportion differences between MI and MC conditions in the imitation-inhibition task.

Moreover, Experiment 2b was designed to detect an effect size as small as $\eta^2_p = .160$. Given that the proportion congruency effect in the unbiased task could be smaller than in the biased task, it is possible that the experiment lacked power to detect such an effect. Thus, in Experiment 3 we collected data from a larger sample to detect a smaller effect size or eventually reach a firmer conclusion in case of a null finding.

Experiment 3

Method

This experiment was preregistered before data collection at <https://osf.io/vtbxj/>.

Participants

Seventy-eight undergraduates (39 females; $M_{age} = 23.97$ years; $SD_{age} = 6.39$) from Rutgers University were recruited between April and June 2024 to participate in Experiment 3 in exchange for course credit. In the sample of participants, 28% identified themselves as white-non-Hispanic, 22% as white-Hispanic, 25% as black, 8% as Asian or Pacific Island, 5% as Native American and 10% elected not to answer. All were right-handed, had normal or corrected-to-normal vision and were naïve with respect to the purpose of the experiment.

A sensitivity analysis revealed that with a sample size of 78 participants and an alpha level of .05, we had 80% power to detect an effect size as small as $\eta^2_p = .10$ in a 2 x 2 x 2 repeated measures ANOVA.

Material, design and procedure

The material and design were the same as in Experiment 2b, except that in the imitation-inhibition task, there were 32 congruent trials and 84 incongruent trials in the MI condition. Conversely, in the MC condition, there were 84 congruent trials and 32 incongruent trials in the imitation-inhibition task. For the Simon task there were 24 congruent trials and 24 incongruent trials in both the MC and MI conditions.

Results

Following the pre-registration, we checked whether any participants showed an average error rate above 40%. No participant had to be excluded based on this criterion.

Trials with no response (0.47 %) and with RT less than 100 ms (0.09 %) were excluded from analyses. The outlier detection procedure applied to the remaining correct RTs resulted in the exclusion of 2.37 % of trials. The results of Experiment 3 are presented in Table 4.

LISAS were submitted to an ANOVA with Proportion (MI vs. MC), Congruency (Congruent vs. Incongruent) and Task (Simon vs. Imitation) as within-participant factors. There was a significant main effect of Task, $F(1, 77) = 441.12, p < .001, \eta^2_p = .851$ and a significant main effect of Congruency, $F(1, 77) = 144.47, p < .001, \eta^2_p = .652$. As in experiments 2a and 2b, a significant Task x Congruency interaction, $F(1, 77) = 49.87, p < .001, \eta^2_p = .393$, indicated a larger congruency effect in the Simon task (462 vs. 525) than in the Imitation task (428 vs. 448). The main effect of Proportion was not significant, $F(1, 77) = 1.300, p = .258, \eta^2_p < .001$. Proportion interacted significantly with Congruency, $F(1, 77) = 5.961, p = .017, \eta^2_p = .072$, showing a proportion congruency effect, such that, irrespective of the task, the difference between incongruent and congruent trials in the MI condition (36 ms) was smaller than that measured in the MC condition (47 ms). Again, the Proportion x Congruency x Task interaction was not significant, $F(1, 77) = 0.403, p = .527, \eta^2_p < .01$ (Figure 4). Paralleling the analyses conducted in Experiments 2a and 2b, we contrasted the congruency effect ($\text{Incongruent}_{\text{LISAS}} - \text{Congruent}_{\text{LISAS}}$) as a function of proportion in each task separately. In the Imitation task, the amplitude of the congruency effect was 27 ms, 95% CI [16, 36] in the MC condition and it was significantly larger than the 14 ms congruency effect, 95% CI [8, 19] in the MI condition, $t(77)$

= 2.482, $p = .015$, $d = 0.281$, $\eta^2_p = .074$. In the Simon task, the congruency effect was 68 ms, 95% CI [53, 82] in the MC condition and 60 ms, 95% CI [48, 72] in the MI condition. The difference between the two conditions was not significant, $t(77) = 1.161$, $p = .249$, $d = 0.132$, $\eta^2_p = .017$, and a Bayesian t -test indicated moderate evidence in favor of the null hypothesis, $BF_{01} = 4.200$ (this test was omitted in the preregistration but was justified to assess evidence of no difference).

Table 4. Means \pm Standard Errors of the Response Times (ms), Error Rates, and linear integrated speed-accuracy scores (ms) in Experiment 3.

Task	Proportion	Congruency					
		Congruent			Incongruent		
		LISAS	RT	ER	LISAS	RT	ER
Simon	Mostly congruent	457 \pm 8	444 \pm 7	0.03 \pm 0.01	524 \pm 12	491 \pm 10	0.08 \pm 0.01
	Mostly Incongruent	467 \pm 8	454 \pm 7	0.03 \pm 0.01	527 \pm 12	494 \pm 9	0.08 \pm 0.01
Imitation	Mostly congruent	424 \pm 8	407 \pm 8	0.04 \pm 0.01	451 \pm 10	427 \pm 8	0.06 \pm 0.01
	Mostly Incongruent	433 \pm 9	415 \pm 8	0.05 \pm 0.01	447 \pm 9	426 \pm 8	0.05 \pm 0.01

Note. LISAS = Linear Integrated Speed-Accuracy Score, RT = Reaction Time, ER = Error Rate

The results of Experiment 3 confirm those from Experiment 2b. Specifically, manipulating proportion congruency within the imitation-inhibition task did not significantly influence the magnitude of the congruency effect in the non-social Simon task. It is also noteworthy that, as in Experiment 2b, both the amplitude of the imitative congruency effect and its modulation by proportion were smaller than those observed in Experiment 1. Thus, despite the adjustments made to the study design, it appears that the inclusion of Simon task trials affected imitation interference. We will return to this point in the General discussion.

General discussion

The present study aimed to investigate the specificity of the processes regulating automatic imitation. We first tested whether imitation interference measured in the imitation-inhibition task is sensitive to the proportion of congruent to incongruent trials (Experiment 1). In Experiments 2a, 2b and 3, the imitation-inhibition task was mixed with the Simon task, allowing

to manipulate proportion congruency in one task or the other. We reasoned that if imitation is regulated by the same domain-general control processes as those involved in non-social conflict tasks (Wager et al., 2005), one should be able to observe (i) a proportion congruency effect on imitation interference and (ii), most critically, transfers of proportion congruency effects between the imitation-inhibition task and the non-social Simon task.

The results of Experiment 1 showed that a proportion congruency effect can be induced in the context of the imitation-inhibition task. Paralleling what has been observed in non-social conflict tasks like the Stroop, flanker and Simon tasks (Bugg, 2017; Kane & Engle, 2003; Wühr et al., 2015), imitation interference was reduced in a condition with a higher (vs. lower) proportion of incongruent trials. In typical conflict tasks, the reduction of interference effects in conditions with high proportion of incongruent trials is thought to reflect adjustments of cognitive control settings (Botvinick et al., 2001; Bugg, 2017). In Experiment 2a, proportion congruency manipulation was implemented in the 'non-social' Simon task. As expected, the size of the Simon effect was reduced in the MI condition relative to the MC condition. Critically, imitation interference was also reduced in the MI condition. Thus, the control processes recruited by Simon-like conflict seem to modulate automatic imitation as well.

These findings are consistent with the hypothesis that the control of automatic imitation relies on domain-general processes (Darda et al., 2018; Ramsey & Ward, 2020). The control-based account of proportion congruency effects suggests that the frequent experience of conflict in the MI condition prompts a sustained heightening of control (Botvinick et al., 2001; Bugg, 2017). From there, the results of Experiment 2a would suggest that in the MI condition, the frequent experience of conflict trials in the Simon task triggered adjustments in domain-general control mechanisms that are recruited to deal with this type of conflict (Wager et al., 2005). Then, the adjustments induced by the proportion manipulation in the Simon task transferred to the imitation-inhibition task because these same domain-general control processes are also recruited to deal with imitation interference.

However, in Experiments 2b and 3, we manipulated the proportion congruency in the imitation-inhibition task and found no significant transfer of the proportion congruency effect

to the Simon task. That is, although the amplitude of imitation interference was reduced in the MI vs. MC condition, this was not the case for the Simon effect. This finding is at odds with the domain-general account of imitation control. Thus, if we take the results of Experiments 1 and 2a as consistent with the domain-general account, we face conflicting results. While remaining cautious, other findings from our study, although unanticipated, provide more insight into this apparent contradiction. In particular, these findings may explain why, even assuming that imitation control is indeed underpinned by domain-general control processes, we did not observe a transfer of proportion congruency from the imitation task to the Simon task in Experiments 2b and 3.

First, one result that stands out from Experiments 2a, 2b, and 3 is that the magnitude of the imitative congruency effect was smaller than that of the Simon effect, in line with previous work (Catmur & Heyes, 2010). Dealing with Simon-type conflict may therefore recruit control processes more strongly than dealing with imitation interference. As a consequence, even if the same control processes regulate both types of congruency effects, the amount of conflict experienced in the Simon task would have a stronger influence on the imitation-inhibition task than vice versa, which may partly explain why we observed a transfer from the Simon to the imitation task, but not the other way around. Second, consistent with this idea, it is noteworthy that in Experiment 1, the imitative congruency effect ranged from 44 ms ($\eta^2_p = 0.48$, MI condition) to 139 ms ($\eta^2_p = 0.61$, MC Condition)², while in the other experiments, where the imitation task was combined with the Simon task, this effect was less than 27 ms ($\eta^2_p < 0.33$) even in the MC condition. The influence of Simon task trials on imitation interference in these experiments is difficult to reconcile with specific regulatory mechanisms of imitation. Instead, this influence could be well explained by the existence of control mechanisms that are common to both the imitation task and the Simon task. The introduction of the Simon-type conflict may have increased the mobilization of cognitive control processes,

² As part of another project, we employed the same automatic imitation task (without Simon task trials), in an experiment (55 participants) with 40% congruent trials, 40% incongruent trials, and 20% neutral trials. This experiment yielded an imitative congruency effect of 53 ms ($\eta^2_p = 0.70$).

hence affecting the size of imitation interference because the same resources are recruited in the imitation-inhibition task. Thus, taken together, our findings are to some extent consistent with the hypothesis that the regulation of automatic imitation relies on domain-general mechanisms. Of course, this conclusion should be treated with caution, as it is partly based on post hoc interpretations, and further studies are needed to fully substantiate it.

Another contribution of the present study is the demonstration, across several experiments, of proportion congruency effects on imitative conflict. These results are in line with those reported in the study by Gordon et al. (2020), which also showed an effect of proportion congruency in the imitation-inhibition task (but see also Hogeveen & Obhi, 2013). Interestingly, these authors argued that the reduction of imitation interference by increasing the proportion of incongruent trials casts some doubt on the truly automatic nature of automatic imitation. We do not share this conclusion. Indeed, there is now considerable evidence that phenomena considered to be highly automatic can be modulated by the task context or internal goals. For example, the ability of a stimulus to trigger attentional capture has been found to depend on the link between that stimulus and the current task-set (Folk & Remington, 1998). Similarly, the influence of proportion congruency has been demonstrated on various effects (Bugg, 2017; Bugg & Crump, 2012), including the Stroop, flanker, and Simon effects, which are assumed to result from the automatic processing of task-irrelevant information (Ulrich et al., 2015). Thus, the modulation of imitation-interference by proportion congruency is not necessarily a sign of a non-automatic phenomenon. Instead, it may indicate an automatic imitation process that is modulated by top-down influences of cognitive control (Cracco et al., 2018; Heyes, 2011).

As explained in the Introduction, proportion congruency effects are thought to be mediated by control modes that are likely to bias treatments of both task-irrelevant and task-relevant information (Botvinick et al., 2001; Bugg, 2017). It is difficult to dissociate these two mechanisms of action as they can operate in parallel or interdependently to generate the proportion congruency effects (Braver, 2012; Bugg, 2017; Murphy et al., 2020). While keeping this in mind, it is interesting to note that there is evidence that proportion manipulation in the

context of the Stroop task influences the processing of irrelevant information (Bugg et al., 2011). In the same vein, research on the Simon effect points to the role of suppression (vs. activation) mechanisms in the resolution of this type of conflict (e.g. Cespón et al., 2020; Ridderinkhof, 2002). Importantly, and consistent with this view, it has been demonstrated that increasing attentional focus on the target stimulus has no effect on the size of the Simon effect (Hommel, 1993). Furthermore, as already mentioned, the results of Experiment 1, where neutral trials were not affected by proportion, suggest that the manipulation of proportion congruency in the context of the imitation-inhibition task influenced mechanisms dealing with the irrelevant information (Cross & Iacoboni, 2014). On this basis, regardless of whether the underlying mechanisms are domain-general or domain-specific, a tentative hypothesis is that MI conditions reduced imitation or Simon effects by enhancing the inhibition of task-irrelevant information, namely spatial information in the Simon task and hand movement stimuli in the imitation-inhibition task.

An essential aspect of our prior reasoning is that the transfer from the Simon task to the imitation-inhibition task observed in Experiment 2a is indicative of the engagement of domain-general control mechanisms in the regulation of automatic imitation. But two different perspectives deserve to be discussed. First, one might object that the repeated experience of conflict when performing the Simon task in the MI condition could also lead participants to employ various domain-general, task-related strategies to improve performance, such as remembering of S-R rules or responding quickly while avoiding errors, which could then be transferred to the imitation task. However, proportion congruency effects have been linked to control mechanisms involved in conflict resolution rather than general strategies (Braver, 2012; Bugg, 2017; Murphy et al., 2020). Moreover, the transfer of these effects across tasks can be altered by subtle task variations (see below) (Bräutigam et al., 2023), which argue against the role of general, task-related strategies. Finally, we can also take into account how performance in the imitation-inhibition task was influenced by proportion congruency. If such kinds of general task-related processes were indeed affected by the proportion manipulation, we should also have observed changes in performance on neutral trials in Experiment 1. This

was not the case. Again, this absence of an effect of proportion congruency on neutral trials suggests that the proportion manipulation specifically affected mechanisms recruited to deal with conflict, rather than general strategies.

Another related possibility to consider is that the mobilization of domain-general control mechanisms to deal with conflict in the Simon task would influence mechanisms of self-other distinction. However, there are several arguments against this perspective. First, if imitation interference is indeed resolved by a self-other discrimination mechanism, one might ask why an additional and potentially redundant general selection mechanism would also be recruited. Relatedly, this hypothesis of transfer of conflict-related adaptation between distinct domain-specific and domain-general processes is at odds with the fact that the transfer of proportion congruency effects between tasks is not systematic in the literature (Bausenhardt et al., 2021; Braem et al., 2011; Bräutigam et al., 2023; Wühr et al., 2015). For instance, research has found an absence of transfer across responses modalities (Braem et al., 2011). Recent work has also failed to show transfer when the modality of the irrelevant dimension differed between the two tasks, even though the relevant dimension remained the same (Bräutigam et al., 2023). Finally, as noted above, the presence of proportion congruency effects in the imitation-inhibition task mirrors what has been observed in various (non-social) conflict tasks and interpreted in terms of adaptation of domain-general control processes (Botvinick et al., 2001; Bugg, 2017). Therefore, the domain-general account offers a parsimonious explanation for the existence of proportion congruency effects in the imitation-inhibition task and of their transfer from the Simon task to the imitation-inhibition task.

In sum, although caution is warranted, the effects observed in the present study can be interpreted as reflecting shared domain-general control processes between the Simon and the imitation-inhibition task. To be clear, we suggest that the present findings can be seen as providing some evidence that imitation control cannot be restricted to a domain-specific mechanism of self-other discrimination, but relies critically on domain-general control processes, such as those mobilized in Stroop-like tasks or Simon tasks. This view, along with our demonstration of proportion congruency effect in imitative conflict, is well in line with some

neurophysiological findings. Indeed, using TMS, Cross and Iacoboni (2014) have found that the preparation to counter-imitate finger movements (vs. mere observation or preparation to imitate) was associated with a reduction of motor resonance. This type of modulation fits with our finding that increasing the proportion of incongruent trials reduced imitation interference. Using fMRI and dynamic causal modeling, Cross et al. (2013) sought to identify the neural network responsible for the control of imitation. Their results suggest that the mPFC and anterior cingulate cortex (ACC) play a role in conflict detection, whereas the anterior insula would be involved in the resolution of conflict, in interaction with the mirror system. Considering the documented roles of the ACC and the insula in the resolution of different types of conflict, Cross et al. (2013) have proposed a model in which these brain structures form a domain-general conflict resolution system that regulates mirror activity. This domain-general system interacts with a domain-specific system involving the mPFC, which would be responsible for determining agency and thereby defining the self-generated action representation (self-other discrimination) (but see Introduction for critics of a specific role of the mPFC). An important question that remains is whether the modulation of automatic imitation occurs at the level of the mirror system itself, its input or its output.

In the present study, we have interpreted the effects of proportion congruency by drawing on the dominant control-based account (Bugg, 2017). However, other interpretations of the proportion congruency effect have been offered. In particular, it has been suggested that the effect may reflect learning of stimulus-response contingencies (Schmidt & Besner, 2008). For example, when performing the Stroop color-naming task in the MI condition, the color green will appear frequently with the incongruent word “red”. Therefore, under these conditions, the irrelevant dimension or stimulus becomes predictive of the correct answer, such that participants can learn to select the (incongruent) “green response” whenever they see the word red, which would thus facilitate response selection on these incongruent trials. This kind of learning may constitute an alternative or an additional mechanism leading to the proportion congruency effect. We cannot exclude that contingency learning occurred in our experiments. However, this cannot explain the transfer effects we observed in Experiment 2a,

such that the proportion manipulation in the Simon task influenced performance in both that biased task and the other, unbiased imitation-inhibition task. More specifically, stimulus-response learning cannot account for the modulation of performance in the unbiased task because in this task (which contains 50% congruent and 50% incongruent trials), the irrelevant dimension is non-predictive of the correct response, i.e. an irrelevant feature appears equally often with a congruent or incongruent relevant feature (Bugg, 2017; Wühr et al., 2015). In fact, the transfer that we observed in Experiment 2a supports the control-based account of proportion congruency effects³.

A potential limit to the approach employed in this study needs to be addressed. To neutralize the potential confound of the left-right spatial correspondence between the response and stimulus hands in the imitation-inhibition task, we employed a common procedure in which the hand stimulus was displayed rotated 90 degrees counterclockwise relative to the participant's hand (Cracco et al., 2018; Gordon et al., 2020; Hogeveen & Obhi, 2013). Still, another issue has been pointed out with this method. Indeed, there is evidence that we tend to associate 'up' with 'right' and 'down' with 'left' (Weeks & Proctor, 1990). Thus, the imitation effect is potentially confounded with an effect of orthogonal compatibility. For example, an observed index finger movement could prime an index response because of imitation and/or because it appears as below the midline of the screen, hence priming a left (i.e. index) response. Importantly, if the two effects were confounded, a reinforcement of the orthogonal spatial compatibility effect would result in an increase of the imitation effect. Thus, the presence of such an effect of orthogonal spatial compatibility (due to an up-right/down-left association) in our experimental setup could have contributed to the transfer we observed

³ To clarify the origin of these effects and as suggested by a reviewer, we also conducted analyses of the congruency sequence effects, i.e. whether the magnitude of the congruency effect on trial n varied as a function of the congruency on trial $n-1$ (Gratton et al., 1992). Sequential congruency effects were observed across the three experiments. The size of the congruency effect is reduced after incongruent trials. In line with other work (Funes et al., 2010; Torres-Quesada et al., 2013), the analyses of Experiments 2a, 2b and 3 showed a sequential congruency effect when the same type of conflict occurred on two consecutive trials, but not for task alternation (see Supplementary materials). Thus, congruency sequence effects may, at least in part, explain the effects of proportion congruency that we observed in the biased task.

between the Simon and imitation-inhibition tasks. However, there are arguments against this possibility. First, previous work suggests that a hand stimulus rotated counterclockwise, as used in the present study, either does not produce orthogonal compatibility effects (Jiménez et al., 2012), or if it does, it takes the form of a down-right/up-left advantage (Czekóová et al., 2021). In the latter case, orthogonal compatibility cannot mediate the transfer of proportion congruency effects from the Simon task toward the imitation-inhibition task we observed in Experiment 2a. Indeed, if one assumes the presence of an orthogonal spatial compatibility effect working against imitation, then the reduction of this spatial effect by the increase of the proportion of incongruent trials in the Simon task would result in the amplification of imitation effects. But what we found was a reduction of imitation interference when the proportion of incongruent Simon trials was increased. Finally, we conducted a complementary experiment in which we tested whether the hand stimuli used in our study influenced the selection of a right or left response. We found no evidence for orthogonal spatial compatibility effects (See Supplementary material).

The precise mechanisms involved in the effects we observed remain to be determined. Furthermore, we mixed an imitation-inhibition task with a Simon task, with the objective of maintaining certain similarities between the tasks and thus introducing Simon-type trials without major modifications to the typical imitation-inhibition task. However, the use of the Simon task raises the problem of spatial compatibility effects that could be also present in the imitation-inhibition task. We have put forward arguments to exclude this possibility. In future work, it would be particularly relevant to test the transfer of proportion congruency effects between imitation and another non-social task without spatial compatibility effects, such as the Stroop task or the flanker task. Although the present study has certain limitations, we believe that the approach developed may constitute a promising line of investigation for the behavioral and neurophysiological study of the control mechanisms of imitation and mirror activity.

Another limitation of the present study relates to ethnicity influencing the amplitude of automatic imitation, as a mismatch between observed and participant's own skin color or

group membership has been found to reduce automatic imitation of facial expressions (Bourgeois, & Hess, 2008; but see Rauchbauer et al., 2018, for imitation of hand movements). In the present study we did not test for the influence of ethnicity (collecting ethnicity data for individual subjects and connecting that to performance was not part of our protocol). We presented white hands as stimuli, and we thus cannot exclude that the amplitude of automatic imitation changes as a function of overlap in skin color between the hand stimulus and the participant. Although we have no reason to anticipate that this match/mismatch of skin color would interact with our within-participant manipulation of proportion congruency, it remains to be tested and provides a useful direction for future research.

The question of whether social cognition and behavior are driven by domain-general or socially specific processes has gained increasing interest in the last few years in psychological and neuroscientific research (Barrett, 2012; Heyes, 2014; Ramsey & Ward, 2020). Recent empirical and theoretical work has highlighted the so far underestimated role of domain-general processes in social cognition (Heyes, 2014; Hommel & Wiers, 2017; Ramsey & Ward, 2020). Notably, studies have shown how domain-general processes can contribute to the generation of phenomena typically attributed to specific social processes. For instance, the joint Simon effect has been explained by general processes of action and cognitive control (Bouquet et al., 2023; Dolk et al., 2014). Likewise, attentional cueing has been proposed to explain response biases in perspective taking tasks (Heyes, 2014). Such a deflationary position is also well illustrated by the theory of event coding and its recent developments (Hommel, 2019), which postulate that produced and perceived events, be they social or not, are represented through the same kind of codes, i.e. codes of their sensory consequences, and which further assume that the same control processes operate over these representations (Hommel & Wiers, 2017). Importantly, as pointed out by others, the fact that a social behavior is governed by domain-general control processes does not mean it is not fundamentally a social behavior (Heyes, 2014; Ramsey & Ward, 2020). Furthermore, even if the same general control processes operate over social and non-social representations, this does not preclude some differences in control related to the nature of these representations.

For example, one influential hypothesis suggests that response conflicts are aversive (Dreisbach & Fischer, 2015). Then, in tasks such as the Stroop and flanker tasks, cognitive control would be recruited to reduce the aversive signals triggered by response conflict (Steenbergen et al., 2009). An interesting question for future research would be to examine whether conflict between (social) representations related to self and other, as in the imitation-inhibition task or in joint action tasks (Dolk et al., 2014; Heyes, 2011), is also accompanied by aversive signals and to what extent this would be stronger or weaker than the aversive signals related to conflict between non-social representations.

Conclusion

The ability to regulate automatic imitation is crucial to navigate the social world. Our study provided a set of results that partially validate the hypothesis that imitation control relies on domain-general mechanisms. Despite certain limitations, this research lays the groundwork for a promising approach to understanding imitation control mechanisms. Thus, the present study adds to a growing literature on the role of domain-general vs. domain-specific processes in social cognitive abilities and behaviors.

References

- Barrett, H. C. (2012). A hierarchical model of the evolution of human brain specializations. *Proceedings of the National Academy of Sciences*, 109(supplement_1), 10733–10740. <https://doi.org/10.1073/pnas.1201898109>
- Bausenhart, K. M., Ulrich, R., & Miller, J. (2021). Effects of conflict trial proportion: A comparison of the Eriksen and Simon tasks. *Attention, Perception, & Psychophysics*, 83(2), 810–836. <https://doi.org/10.3758/s13414-020-02164-2>
- Bonini, L., Rotunno, C., Arcuri, E., & Gallese, V. (2023). The mirror mechanism: Linking perception and social interaction. *Trends in Cognitive Sciences*, S1364661322003278. <https://doi.org/10.1016/j.tics.2022.12.010>

- Bonnin, C. A., Houeto, J.-L., Gil, R., & Bouquet, C. A. (2010). Adjustments of conflict monitoring in Parkinson's disease. *Neuropsychology*, *24*(4), 542–546.
<https://doi.org/10.1037/a0018384>
- Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, *108*(3), 624–652.
<https://doi.org/10.1037/0033-295X.108.3.624>
- Bouquet, C. A., Belletier, C., Monceau, S., Chausse, P., Croizet, J. C., Huguet, P., & Ferrand, L. (2023). Joint action with human and robotic co-actors: Self-other integration is immune to the perceived humanness of the interacting partner. *Quarterly journal of experimental psychology (2006)*, 17470218231158481. Advance online publication. <https://doi.org/10.1177/17470218231158481>
- Bourgeois, P., & Hess, U. (2008). The impact of social context on mimicry. *Biological psychology*, *77*(3), 343–352. <https://doi.org/10.1016/j.biopsycho.2007.11.008>
- Braem, S., Verguts, T., & Notebaert, W. (2011). Conflict adaptation by means of associative learning. *Journal of experimental psychology. Human perception and performance*, *37*(5), 1662–1666. <https://doi.org/10.1037/a0024385>
- Brass, M., Bekkering, H., Wohlschläger, A., & Prinz, W. (2000). Compatibility between Observed and Executed Finger Movements: Comparing Symbolic, Spatial, and Imitative Cues. *Brain and Cognition*, *44*(2), 124–143.
<https://doi.org/10.1006/brcg.2000.1225>
- Brass, M., Derrfuss, J., & von Cramon, D. Y. (2005). The inhibition of imitative and overlearned responses: A functional double dissociation. *Neuropsychologia*, *43*(1), 89–98. <https://doi.org/10.1016/j.neuropsychologia.2004.06.018>
- Brass, M., & Heyes, C. (2005). Imitation: Is cognitive neuroscience solving the correspondence problem? *Trends in Cognitive Sciences*, *9*(10), 489–495.
<https://doi.org/10.1016/j.tics.2005.08.007>
- Brass, M., Zysset, S., & von Cramon, D. Y. (2001). The Inhibition of Imitative Response Tendencies. *NeuroImage*, *14*(6), 1416–1423. <https://doi.org/10.1006/nimg.2001.0944>

- Bräutigam, L. C., Leuthold, H., Mackenzie, I. G., & Mittelstädt, V. (2023). Exploring behavioral adjustments of proportion congruency manipulations in an Eriksen flanker task with visual and auditory distractor modalities. *Memory & Cognition*.
<https://doi.org/10.3758/s13421-023-01447-x>
- Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences*, 16(2), 106–113.
<https://doi.org/10.1016/j.tics.2011.12.010>
- Bugg, J. M. (2014). Conflict-triggered top-down control: Default mode, last resort, or no such thing? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 40(2), 567–587. <https://doi.org/10.1037/a0035032>
- Bugg, J. M. (2017). Context, Conflict, and Control. In T. Egner (Ed.), *The Wiley Handbook of Cognitive Control* (pp. 79–96). John Wiley & Sons, Ltd.
<https://doi.org/10.1002/9781118920497.ch5>
- Bugg, J. M., & Crump, M. J. C. (2012). In Support of a Distinction between Voluntary and Stimulus-Driven Control: A Review of the Literature on Proportion Congruent Effects. *Frontiers in Psychology*, 3. <https://doi.org/10.3389/fpsyg.2012.00367>
- Bugg, J. M., Jacoby, L. L., & Chanani, S. (2011). Why it is too early to lose control in accounts of item-specific proportion congruency effects. *Journal of Experimental Psychology: Human Perception and Performance*, 37(3), 844–859.
<https://doi.org/10.1037/a0019957>
- Bukowski, H. (2018). The Neural Correlates of Visual Perspective Taking: A Critical Review. *Current Behavioral Neuroscience Reports*, 5(3), 189–197.
<https://doi.org/10.1007/s40473-018-0157-6>
- Bukowski, H., Todorova, B., Boch, M., Silani, G., & Lamm, C. (2021). Socio-cognitive training impacts emotional and perceptual self-salience but not self-other distinction. *Acta Psychologica*, 216, 103297. <https://doi.org/10.1016/j.actpsy.2021.103297>

- Bunge, S. A., Hazeltine, E., Scanlon, M. D., Rosen, A. C., & Gabrieli, J. D. (2002). Dissociable contributions of prefrontal and parietal cortices to response selection. *NeuroImage*, *17*(3), 1562–1571. <https://doi.org/10.1006/nimg.2002.1252>
- Bunlon, F., Marshall, P. J., Quandt, L. C., & Bouquet, C. A. (2015). Influence of action-effect associations acquired by ideomotor learning on imitation. *PloS one*, *10*(3), e0121617. <https://doi.org/10.1371/journal.pone.0121617>
- Campbell, J. I. D., & Thompson, V. A. (2012). MorePower 6.0 for ANOVA with relational confidence intervals and Bayesian analysis. *Behavior Research Methods*, *44*(4), 1255–1265. <https://doi.org/10.3758/s13428-012-0186-0>
- Catmur, C. (2016). Automatic imitation? Imitative compatibility affects responses at high perceptual load. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(4), 530–539. <https://doi.org/10.1037/xhp0000166>
- Catmur, C., & Heyes, C. (2011). Time course analyses confirm independence of imitative and spatial compatibility. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(2), 409–421. <https://doi.org/10.1037/a0019325>
- Cespón, J., Hommel, B., Korsch, M., & Galashan, D. (2020). The neurocognitive underpinnings of the Simon effect: An integrative review of current research. *Cognitive, affective & behavioral neuroscience*, *20*(6), 1133–1172. <https://doi.org/10.3758/s13415-020-00836-y>
- Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology*, *76*(6), 893–910. <https://doi.org/10.1037/0022-3514.76.6.893>
- Chartrand, T. L., & Lakin, J. L. (2013). The Antecedents and Consequences of Human Behavioral Mimicry. *Annual Review of Psychology*, *64*(1), 285–308. <https://doi.org/10.1146/annurev-psych-113011-143754>
- Cheng, C. M., & Chartrand, T. L. (2003). Self-Monitoring Without Awareness: Using Mimicry as a Nonconscious Affiliation Strategy. *Journal of Personality and Social Psychology*, *85*(6), 1170–1179. <https://doi.org/10.1037/0022-3514.85.6.1170>

- Cieslik, E. C., Mueller, V. I., Eickhoff, C. R., Langner, R., & Eickhoff, S. B. (2015). Three key regions for supervisory attentional control: Evidence from neuroimaging meta-analyses. *Neuroscience & Biobehavioral Reviews*, *48*, 22–34.
<https://doi.org/10.1016/j.neubiorev.2014.11.003>
- Cohen, J. D. (2017). Cognitive Control: Core Constructs and Current Considerations. In T. Egner (Ed.), *The Wiley Handbook of Cognitive Control* (pp. 1–28). John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781118920497.ch1>
- Cook, R., Bird, G., Catmur, C., Press, C., & Heyes, C. (2014). Mirror neurons: From origin to function. *Behavioral and Brain Sciences*, *37*(2), 177–192.
<https://doi.org/10.1017/S0140525X13000903>
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201–215.
<https://doi.org/10.1038/nrn755>
- Cracco, E., Bardi, L., Desmet, C., Genschow, O., Rigoni, D., De Coster, L., Radkova, I., Deschrijver, E., & Brass, M. (2018). Automatic imitation: A meta-analysis. *Psychological Bulletin*, *144*(5), 453–500. <https://doi.org/10.1037/bul0000143>
- Crescentini, C., Mengotti, P., Grecucci, A., & Rumiati, R. I. (2011). The effect of observed biological and non biological movements on action imitation: an fMRI study. *Brain research*, *1420*, 80–92. <https://doi.org/10.1016/j.brainres.2011.08.077>
- Cross, K. A., & Iacoboni, M. (2014). To imitate or not: Avoiding imitation involves preparatory inhibition of motor resonance. *NeuroImage*, *91*, 228–236.
<https://doi.org/10.1016/j.neuroimage.2014.01.027>
- Cross, K. A., Torrisi, S., Reynolds Losin, E. A., & Iacoboni, M. (2013). Controlling automatic imitative tendencies: interactions between mirror neuron and cognitive control systems. *NeuroImage*, *83*, 493–504.
<https://doi.org/10.1016/j.neuroimage.2013.06.060>
- Czekóová, K., Shaw, D. J., Lamoš, M., Špiláková, B., Salazar, M., & Brázdil, M. (2021). Imitation or Polarity Correspondence? Behavioural and Neurophysiological Evidence

- for the Confounding Influence of Orthogonal Spatial Compatibility on Measures of Automatic Imitation. *Cognitive, Affective, & Behavioral Neuroscience*, 21(1), 212–230. <https://doi.org/10.3758/s13415-020-00860-y>
- Darda, K. M., Butler, E. E., & Ramsey, R. (2018). Functional Specificity and Sex Differences in the Neural Circuits Supporting the Inhibition of Automatic Imitation. *Journal of Cognitive Neuroscience*, 30(6), 914–933. https://doi.org/10.1162/jocn_a_01261
- Darda, K. M., & Ramsey, R. (2019). The inhibition of automatic imitation: A meta-analysis and synthesis of fMRI studies. *NeuroImage*, 197, 320–329. <https://doi.org/10.1016/j.neuroimage.2019.04.059>
- Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., & Liepelt, R. (2014). The joint Simon effect: A review and theoretical integration. *Frontiers in Psychology*, 5. <https://doi.org/10.3389/fpsyg.2014.00974>
- Dreisbach, G., & Fischer, R. (2015). Conflicts as Aversive Signals for Control Adaptation. *Current Directions in Psychological Science*, 24(4), 255–260. <https://doi.org/10.1177/0963721415569569>
- Duffy, K. A., & Chartrand, T. L. (2015). Mimicry: Causes and consequences. *Current Opinion in Behavioral Sciences*, 3, 112–116. <https://doi.org/10.1016/j.cobeha.2015.03.002>
- Dugué, L., Merriam, E. P., Heeger, D. J., & Carrasco, M. (2018). Specific Visual Subregions of TPJ Mediate Reorienting of Spatial Attention. *Cerebral Cortex*, 28(7), 2375–2390. <https://doi.org/10.1093/cercor/bhx140>
- Duncan J. (2010). The multiple-demand (MD) system of the primate brain: mental programs for intelligent behaviour. *Trends in cognitive sciences*, 14(4), 172–179. <https://doi.org/10.1016/j.tics.2010.01.004>
- Egner, T. (2014). Creatures of habit (and control): A multi-level learning perspective on the modulation of congruency effects. *Frontiers in Psychology*, 5. <https://doi.org/10.3389/fpsyg.2014.01247>

- Fedorenko, E., Duncan, J., & Kanwisher, N. (2013). Broad domain generality in focal regions of frontal and parietal cortex. *Proceedings of the National Academy of Sciences*, *110*(41), 16616–16621. <https://doi.org/10.1073/pnas.1315235110>
- Folk, C. L., & Remington, R. (1998). Selectivity in distraction by irrelevant featural singletons: Evidence for two forms of attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(3), 847–858. <https://doi.org/10.1037/0096-1523.24.3.847>
- Funes, M. J., Lupiáñez, J., & Humphreys, G. (2010). Sustained vs. transient cognitive control: Evidence of a behavioral dissociation. *Cognition*, *114*(3), 338–347. <https://doi.org/10.1016/j.cognition.2009.10.007>
- Geng, J. J., & Vossel, S. (2013). Re-evaluating the role of TPJ in attentional control: Contextual updating? *Neuroscience & Biobehavioral Reviews*, *37*(10), 2608–2620. <https://doi.org/10.1016/j.neubiorev.2013.08.010>
- Gordon, A., Geddert, R., Hogeveen, J., Krug, M. K., Obhi, S., & Solomon, M. (2020). Not So Automatic Imitation: Expectation of Incongruence Reduces Interference in Both Autism Spectrum Disorder and Typical Development. *Journal of Autism and Developmental Disorders*, *50*(4), 1310–1323. <https://doi.org/10.1007/s10803-019-04355-9>
- Gratton, G., Coles, M. G., & Donchin, E. (1992). Optimizing the use of information: strategic control of activation of responses. *Journal of experimental psychology. General*, *121*(4), 480–506. <https://doi.org/10.1037//0096-3445.121.4.480>
- Heyes, C. (2011). Automatic imitation. *Psychological Bulletin*, *137*(3), 463–483. <https://doi.org/10.1037/a0022288>
- Heyes, C. (2014). Submentalizing: I Am Not Really Reading Your Mind. *Perspectives on Psychological Science*, *9*(2), 131–143. <https://doi.org/10.1177/1745691613518076>
- Heyes, C., & Catmur, C. (2022). What Happened to Mirror Neurons? *Perspectives on Psychological Science*, *17*(1), 153–168. <https://doi.org/10.1177/1745691621990638>

- Hogeveen, J., & Obhi, S. S. (2013). Automatic imitation is automatic, but less so for narcissists. *Experimental Brain Research*, 224(4), 613–621.
<https://doi.org/10.1007/s00221-012-3339-6>
- Hommel B. (1993). The role of attention for the Simon effect. *Psychological research*, 55(3), 208–222. <https://doi.org/10.1007/BF00419608>
- Hommel, B. (2019). Theory of Event Coding (TEC) V2.0: Representing and controlling perception and action. *Attention, Perception, & Psychophysics*, 81(7), 2139–2154.
<https://doi.org/10.3758/s13414-019-01779-4>
- Hommel, B., & Wiers, R. W. (2017). Towards a Unitary Approach to Human Action Control. *Trends in Cognitive Sciences*, 21(12), 940–949.
<https://doi.org/10.1016/j.tics.2017.09.009>
- Iacoboni, M. (2009). Imitation, Empathy, and Mirror Neurons. *Annual Review of Psychology*, 60(1), 653–670. <https://doi.org/10.1146/annurev.psych.60.110707.163604>
- JASP Team. (2020). *JASP* ((Version 0.14)). <https://jasp>
- Jiménez, L., Recio, S., Méndez, A., Lorda, M. J., Permuy, B., & Méndez, C. (2012). Automatic imitation and spatial compatibility in a key-pressing task. *Acta Psychologica*, 141(1), 96–103. <https://doi.org/10.1016/j.actpsy.2012.07.007>
- Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General*, 132(1), 47–70.
<https://doi.org/10.1037/0096-3445.132.1.47>
- Keysers, C., Paracampo, R., & Gazzola, V. (2018). What neuromodulation and lesion studies tell us about the function of the mirror neuron system and embodied cognition. *Current Opinion in Psychology*, 24, 35–40.
<https://doi.org/10.1016/j.copsyc.2018.04.001>
- Lakin, J. L., Chartrand, T. L., & Arkin, R. M. (2008). I Am Too Just Like You: Nonconscious Mimicry as an Automatic Behavioral Response to Social Exclusion. *Psychological Science*, 19(8), 816–822. <https://doi.org/10.1111/j.1467-9280.2008.02162.x>

- Marsh, A. A. (2018). The neuroscience of empathy. *Current Opinion in Behavioral Sciences*, 19, 110–115. <https://doi.org/10.1016/j.cobeha.2017.12.016>
- Mengotti, P., Corradi-Dell'Acqua, C., & Rumiati, R. I. (2012). Imitation components in the human brain: An fMRI study. *NeuroImage*, 59(2), 1622–1630. <https://doi.org/10.1016/j.neuroimage.2011.09.004>
- Mitchell, J. P. (2008). Activity in Right Temporo-Parietal Junction is Not Selective for Theory-of-Mind. *Cerebral Cortex*, 18(2), 262–271. <https://doi.org/10.1093/cercor/bhm051>
- Morey, R. D., Rouder, J. N., & Jamil, T. (2015). *Bayes Factor: Computation of bayes factors for common designs. R package version 0.9.12-4.2*. <https://CRAN.R-project.org/package=BayesFactor>
- Murphy, J., Devue, C., Corballis, P. M., & Grimshaw, G. M. (2020). Proactive Control of Emotional Distraction: Evidence From EEG Alpha Suppression. *Frontiers in Human Neuroscience*, 14, 318. <https://doi.org/10.3389/fnhum.2020.00318>
- Quesque, F., & Brass, M. (2019). The Role of the Temporoparietal Junction in Self-Other Distinction. *Brain Topography*, 32(6), 943–955. <https://doi.org/10.1007/s10548-019-00737-5>
- Qureshi, A. W., Bretherton, L., Marsh, B., & Monk, R. L. (2020). Stimulation of the dorsolateral prefrontal cortex impacts conflict resolution in Level-1 visual perspective taking. *Cognitive, Affective, & Behavioral Neuroscience*, 20(3), 565–574. <https://doi.org/10.3758/s13415-020-00786-5>
- Ramsey, R. (2018). What are reaction time indices of automatic imitation measuring? *Consciousness and Cognition*, 65, 240–254. <https://doi.org/10.1016/j.concog.2018.08.006>
- Ramsey, R., Darda, K. M., & Downing, P. E. (2019). Automatic imitation remains unaffected under cognitive load. *Journal of Experimental Psychology: Human Perception and Performance*, 45(5), 601–615. <https://doi.org/10.1037/xhp0000632>
- Ramsey, R., & Ward, R. (2020). Putting the Nonsocial Into Social Neuroscience: A Role for Domain-General Priority Maps During Social Interactions. *Perspectives on*

Psychological Science, 15(4), 1076–1094.

<https://doi.org/10.1177/1745691620904972>

Rauchbauer, B., Pfabigan, D. M., & Lamm, C. (2018). Event-related potentials of automatic imitation are modulated by ethnicity during stimulus processing, but not during motor execution. *Scientific reports*, 8(1), 12760. <https://doi.org/10.1038/s41598-018-30926-4>

Ridderinkhof, K. R. (2002). Activation and suppression in conflict tasks: Empirical clarification through distributional analyses. In W. Prinz & B. Hommel (Eds.), *Common mechanisms in perception and action. Attention & performance* (pp. 494–519). Oxford (UK): Oxford University Press

Santiesteban, I., White, S., Cook, J., Gilbert, S. J., Heyes, C., & Bird, G. (2012). Training social cognition: From imitation to Theory of Mind. *Cognition*, 122(2), 228–235. <https://doi.org/10.1016/j.cognition.2011.11.004>

Schmidt, J. R., & Besner, D. (2008). The Stroop effect: Why proportion congruent has nothing to do with congruency and everything to do with contingency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34(3), 514–523. <https://doi.org/10.1037/0278-7393.34.3.514>

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: A meta-analysis of functional brain imaging studies. *Neuroscience & Biobehavioral Reviews*, 42, 9–34. <https://doi.org/10.1016/j.neubiorev.2014.01.009>

Sowden, S., & Catmur, C. (2015). The Role of the Right Temporoparietal Junction in the Control of Imitation. *Cerebral Cortex*, 25(4), 1107–1113. <https://doi.org/10.1093/cercor/bht306>

Sowden, S., & Shah, P. (2014). Self-other control: A candidate mechanism for social cognitive function. *Frontiers in Human Neuroscience*, 8. <https://doi.org/10.3389/fnhum.2014.00789>

Spinelli, G., & Lupker, S. J. (2022a). Conflict-monitoring theory in overtime: Is temporal learning a viable explanation for the congruency sequence effect? *Journal of*

- Experimental Psychology: Human Perception and Performance*, 48(5), 497–530.
<https://doi.org/10.1037/xhp0000996>
- Spinelli, G., & Lupker, S. J. (2022b). Robust evidence for proactive conflict adaptation in the proportion-congruent paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, No Pagination Specified-No Pagination Specified.
<https://doi.org/10.1037/xlm0001144>
- Spunt, R. P., & Adolphs, R. (2017). A new look at domain specificity: Insights from social neuroscience. *Nature Reviews Neuroscience*, 18(9), 559–567.
<https://doi.org/10.1038/nrn.2017.76>
- Steenbergen, H. van, Band, G. P. H., & Hommel, B. (2009). Reward Counteracts Conflict Adaptation: Evidence for a Role of Affect in Executive Control. *Psychological Science*, 20(12), 1473–1477. <https://doi.org/10.1111/j.1467-9280.2009.02470.x>
- Stel, M., & Vonk, R. (2009). Empathizing via Mimicry Depends on Whether Emotional Expressions Are Seen as Real. *European Psychologist*, 14(4), 342–350.
<https://doi.org/10.1027/1016-9040.14.4.342>
- Torres-Quesada, M., Funes, M. J., & Lupiáñez, J. (2013). Dissociating proportion congruent and conflict adaptation effects in a Simon–Stroop procedure. *Acta Psychologica*, 142(2), 203–210. <https://doi.org/10.1016/j.actpsy.2012.11.015>
- Ulrich, R., Schröter, H., Leuthold, H., & Birngruber, T. (2015). Automatic and controlled stimulus processing in conflict tasks: Superimposed diffusion processes and delta functions. *Cognitive Psychology*, 78, 148–174.
<https://doi.org/10.1016/j.cogpsych.2015.02.005>
- Vandierendonck, A. (2017). A comparison of methods to combine speed and accuracy measures of performance: A rejoinder on the binning procedure. *Behavior Research Methods*, 49(2), 653–673. <https://doi.org/10.3758/s13428-016-0721-5>
- Vandierendonck, A. (2021). On the Utility of Integrated Speed-Accuracy Measures when Speed-Accuracy Trade-off is Present. *Journal of Cognition*, 4(1), 22.
<https://doi.org/10.5334/joc.154>

- Wager, T. D., Sylvester, C.-Y. C., Lacey, S. C., Nee, D. E., Franklin, M., & Jonides, J. (2005). Common and unique components of response inhibition revealed by fMRI. *NeuroImage*, 27(2), 323–340. <https://doi.org/10.1016/j.neuroimage.2005.01.054>
- Wang, Y., & Hamilton, A. F. de C. (2012). Social top-down response modulation (STORM): A model of the control of mimicry in social interaction. *Frontiers in Human Neuroscience*, 6. <https://doi.org/10.3389/fnhum.2012.00153>
- Wang, Y., Ramsey, R., & de C. Hamilton, A. F. (2011). The Control of Mimicry by Eye Contact Is Mediated by Medial Prefrontal Cortex. *Journal of Neuroscience*, 31(33), 12001–12010. <https://doi.org/10.1523/JNEUROSCI.0845-11.2011>
- Weeks, D. J., & Proctor, R. W. (1990). Salient-features coding in the translation between orthogonal stimulus and response dimensions. *Journal of Experimental Psychology: General*, 119(4), 355–366. <https://doi.org/10.1037/0096-3445.119.4.355>
- Wood, A., Rychlowska, M., Korb, S., & Niedenthal, P. (2016). Fashioning the Face: Sensorimotor Simulation Contributes to Facial Expression Recognition. *Trends in Cognitive Sciences*, 20(3), 227–240. <https://doi.org/10.1016/j.tics.2015.12.010>
- Wühr, P., Duthoo, W., & Notebaert, W. (2015). Generalizing attentional control across dimensions and tasks: Evidence from transfer of proportion-congruent effects. *Quarterly Journal of Experimental Psychology*, 68(4), 779–801. <https://doi.org/10.1080/17470218.2014.966729>

Ethical statement

This study was approved by Rutgers IRB Protocols #Pro2019002031 and #Pro2022002147. Experiments were performed in compliance with local laws and in accordance with the ethical standards set out in the 1964 Declaration of Helsinki.

Peer Review Version