Automatic imitation and spatial compatibility in a key-pressing task

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Automatic imitation has been often confounded with spatial compatibility effects. Heyes (2011) called attention to this confound, and proposed some criteria which must be satisfied before these effects could be unequivocally taken to be an index of the functioning of the human mirror system. Evidence satisfying such criteria has been reported by Catmur and Heyes (2011), using a relatively unfamiliar finger abduction movement. However, because many previous studies relied on more familiar actions, we aimed at testing whether analogous effects could be obtained with a more practiced key-pressing task. In Experiment 1, we used anatomical controls (i.e., views of right vs. left hands) under conditions affording mirror imitation, and showed that spatial compatibility masked the effects of automatic imitation. Experiment 2 used rotated conditions to control for this spatial-anatomical confound, and it showed unequivocal effects of automatic imitation, which were obtained regardless of its relation to the spatial stimulus–response mapping. These results cast some doubts on the interpretation of previous reports relying exclusively on scenes presented from a mirror perspective, and suggest the convenience of using both rotated scenes and anatomical controls in order to assess automatic imitation.

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1. Introduction

Automatic imitation refers to a type of stimulus–response compatibility effect by which the features of an observed task-irrelevant action affect the observer’s action, depending on the degree of compatibility existent between them (Heyes, 2011). Automatic imitation has become a hot topic over the last decade (e.g. Aicken, Wilson, Williams, & Mon-Williams, 2007; Bertenthal, Longo, & Kosobud, 2006; Brass & Heyes, 2005; Catmur & Heyes, 2011; Iacoboni, 2009; Longo & Bertenthal, 2009; Stürmer, Aschersleben, & Prinz, 2000) mainly because it offers a tool for solving the thorny issue of how people map two independent domains, such as that pertaining to the visual encoding of an observed action, and that involved in programming and performing a corresponding motor action.

This "correspondence problem" (Brass & Heyes, 2005) has been addressed in two alternative ways, either by assuming that people come genetically endowed with a “mirror system” or some other structure sustaining these observation–execution links (Jacoboni et al., 1999; Meltzoff, 2002), or by stating that these mappings are progressively learned and generalized through repeated experience with sensorimotor or ideomotor contingencies (Heyes, 2001; Prinz, 1997, 2002), with the help of general mechanisms of learning. Importantly, although these views differ in many of their predictions regarding the origin or the temporal course of imitation, they both conceive the complex forms of deliberate imitation as growing progressively out of more elementary phenomena, which arise automatically from experience without the overt intention to imitate.

In a recent study, Catmur and Heyes (2011) questioned the extent to which currently available evidence has convincingly demonstrated the existence of such automatic imitation effects, and warned against the potential confusion between imitative effects and other forms of stimulus–response compatibility, such as spatial compatibility (see also Aicken et al., 2007; Jansson, Wilson, Williams, & Mon-Williams, 2007). Indeed, if the actions observed by the participants are presented at locations corresponding to those where the target actions are required, then the effects could also be explained in terms of the spatial compatibility between both movements, without appealing to a process of automatic imitation (Jansson et al., 2007). In addition to this confound, Heyes (2011) also highlighted that, in order for an effect to be considered as a strong proof of automatic imitation, it should be observed in contexts in which participants are never instructed to imitate, so that one can be sure that imitation is not part of participants’ intentions, and that the observed effects cannot be the result of a confusion between those blocks requiring imitation and those requiring response to a different cue.

Automatic imitation effects satisfying such criteria were reported by Catmur and Heyes (2011) using a relatively unfamiliar finger abduction movement, which required participants to perform an outward movement of either their index or little finger with respect to the other fingers, in the horizontal plane. However, because there might be differences between the ways in which people imitate or...
resist imitation of these relatively unfamiliar actions, as compared to more familiar or over-learned actions (Calvó-Merino, Glaser, Grezes, Passingham, & Haggard, 2005), and because there is a large number of alleged reports of automatic imitation using variations of more familiar finger movements (Bertenthal et al., 2006; Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschläger, & Prinz, 2000; Longo & Bertenthal, 2005; Longo, Kosobud, & Bertenthal, 2008), we set out to confirm whether Heyes (2011) criteria could be applied to a simpler key-pressing task. This is even more important in light of some recent reports having used similar finger movements to draw inferences on whether or not automatic imitation is affected in populations known to present other imitation deficits, as is the case of people with autism spectrum conditions (Spengler, Bird, & Brass, 2010).

2. Finger movement tasks

In studies using tapping, key-pressing or finger-lifting tasks, participants are required to respond to a discriminative stimulus (usually a digit, a cross, or a colored circle) by using one of two fingers of the same hand, while they are simultaneously presented with a video clip showing an action that is either compatible or incompatible with the required response. Usually, right-handed participants are presented with left-hand scenes, which are easily interpreted as mirror views of the subject’s dominant hand. In these specular imitation conditions, (Koski, Iacoboni, Dubeau, Woods, & Mazziotta, 2003), imitative compatibility is described in terms of finger mapping, in that imitative compatible trials are those in which participants have to use the same finger from their own right hand (i.e., middle or index finger) which was moved in the video by the observed left hand (see Fig. 1 for illustration). The results obtained in these conditions have been interpreted as evidence of automatic imitation, in that the observed movements affected performance even when they were explicitly irrelevant for the task (Aicken et al., 2007; Bertenthal et al., 2000, 2001; Jansson et al., 2007).

However, the two main objections brought up by Catmur and Heyes (2011) can be raised against a direct interpretation of these results as evidence for automatic imitation. On the one hand, some

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**Fig. 1.** A) Illustration of a sample of the trials used in Experiment 1, showing the initial and final states of the irrelevant hand that appears on the screen, the discriminative stimulus (colored circle) that appears below the observed hand toward the end of the scene, and the response required (i.e., pressing the corresponding key with the finger in black). Notice that for the left-hand trials, finger- and spatial compatibility effects were systematically blended, whereas for the right-hand trials these two effects were set in opposition. B) Illustration of a sample of the trials used in Experiment 2, with the observed hands rotated 90° clockwise to control for the spatial effects. Both left-hand and right-hand trials are classified in terms of whether they require a response produced with the same finger (middle or index) which did the tapping movement on the observed scene.
of these studies interleaved imitation and non-imitation blocks (Aicken et al., 2007; Bertenthal et al., 2006, Exp. 1 and 2; Brass et al., 2000), thus casting doubts on whether participants really perceived the displayed movements as irrelevant to their ongoing tasks. On the other hand, the attribution of these effects to an imitation process has been questioned by reports showing that similar results arise even when these scenes are replaced by other video clips showing spatially compatible movements produced by non-biological stimuli, such as a pen, a robotic “hand”, or even a schematic representation of the actions (Jansson et al., 2007; Press, Bird, Flach, & Heyes, 2005). In these latter experiments, the stimuli were orthogonal to the required responses, in order to control for the effects of spatial compatibility. However, because the task arranged in these conditions required participants to produce a composite response, such as opening or closing a semi-open hand by moving the thumb toward or away from the other fingers, one may argue that spatial compatibility in those cases should be better defined in terms of the internal relations established between the two components of these actions, rather than in terms of their absolute spatial coordinates. In any case, if presenting a moving hand is not necessary to produce such compatibility effects, then probably these results should be better explained by appealing to either absolute or relative spatial compatibility effects, rather than as arisen from imitative processes.

To clarify the relative contribution of automatic imitation and of spatial compatibility in these finger movement paradigms, it has been proposed to compare the effect of using either right-hand or left-hand scenes as the irrelevant stimuli. Bertenthal et al. (2006) used this strategy in two independent experiments, in which right-handed participants responded to a discriminative stimulus by using the index or middle fingers from their right-hand, while they saw video clips of either a left hand or a right hand performing similar finger-tapping movements. In their Experiment 1, participants were presented with left-hand scenes, which could be readily interpreted as a mirror reflection of their own moving hand, thus blending spatial and Finger Compatibility effects. More specifically, because the view of a left hand performing an index-finger movement in front of the participants drew attention to the same relative location at which participants had to move their own right-hand index finger, compatible trials in this case were simultaneously spatial and imitatively compatible, whereas incompatible trials were also incompatible with respect to both spatial and imitative criteria. In contrast, in their Experiment 2, participants viewed scenes of a right hand producing the same movements. This confronted spatial and imitative effects, because the observed index and middle fingers now appeared at locations opposite to those corresponding to the locations occupied by the participants’ fingers (see Fig. 1). This reversed arrangement of spatial and finger-identity effects allegedly allowed the authors to disentangle the effects of imitative and spatial factors.

The results of these experiments showed that the overall compatibility effect was higher for the left-hand scenes used in Experiment 1, and also that the spatial factor was responsible for the largest proportion of the effects obtained in Experiment 2. Indeed, for this second experiment, the responses were faster on those trials depicting spatially compatible movements, even though they were performed with a finger opposite to that required for the participant to give an accurate response. The only evidence for automatic imitation obtained in this study came from a comparison between experiments, which showed that the overall compatibility effect was larger in Experiment 1, in which both effects were acting in conjunction, than in Experiment 2, in which they had been set in opposition. A follow-up experiment in which participants were directly instructed to pay attention and to respond to the spatial location of those movements (Experiment 3b), also showed that responding was slightly faster in those blocks displaying a mirror view of the required action (i.e., left-hand scenes, which were imitatively compatible) than in those showing the movement of a transposed hand (right-hand scenes, which were imitatively incompatible).

The results reported by Bertenthal et al. (2006) can be seen as the strongest evidence for automatic imitation of key-pressing to date, but still they cannot be taken as conclusive. First, these effects were obtained in experiments which included some blocks in which participants were explicitly instructed to imitate, and thus they could arguably be affected by the relevance of imitation in previous blocks. Second, the effect of action compatibility was inferred from a comparison between experiments, and thus it must be considered as a post-hoc effect, that should be replicated in the context of a single experiment. Third, in their Experiment 3b, the effect was obtained from a task in which participants were instructed to pay attention to the modeled action, and to respond to a dimension of that action. To the extent that those actions are represented as configurural stimuli (Calvo-Merino, Ehrenberg, Leung, & Haggard, 2010), one may argue that paying attention to some features of these actions could not be completely separated from paying attention to the effectors with which they were performed, and therefore to a confusion between the relevant and irrelevant features of those actions. In sum, the results up to now cannot be taken as conclusive with respect to the existence of automatic imitation in this kind of familiar and well practiced, key pressing tasks.

3. The present experiments

The primary aim of this study was therefore to test whether the automatic imitation effects can be obtained in conditions in which (1) the required response was a familiar key-pressing task, emitted with the participants’ dominant hand; (2) the automatic nature of the effect was not contaminated by including either imitation blocks or tasks requiring participants to pay attention to the modeled actions; and (3) imitation effects were dissociated from spatial compatibility effects by means of two strategies. In Experiment 1, we conceptually replicated Experiments 1 and 2 by Bertenthal et al. (2006), but we did so in a within-participants’ design, by comparing their performance in blocks which blended the effects of automatic imitation and spatial compatibility (i.e., blocks presenting left-hand scenes, affording a mirror-view interpretation), and in blocks which set both effects in opposition, by presenting a right hand, which afforded a transposed-view interpretation. In Experiment 2 we attempted to minimize the role of spatial compatibility, by presenting both types of scenes in an orthogonal arrangement with respect to the observers’ responses. We reasoned that spatial and imitative factors could interact with each other, with the stronger effect contributing to mask the expression of the weaker one. To assess this possibility, in Experiment 2 we replicated the design of Experiment 1, but we rotated the scenes 90° clockwise, so as to minimize the effect of spatial compatibility. Thus, in Experiment 2 the observed scenes were no longer depicting finger movements produced on the left vs. right sides of the computer screen, but rather on its upper vs. lower hemi-fields.

To foreshadow the results of these two experiments, in Experiment 1 we found that spatial compatibility exerted a strong impact on performance, to the point of precluding the expression of automatic imitation effects. In contrast, when these spatial effects were controlled in Experiment 2, the effects of automatic imitation were consistently observed, showing faster RTs when the observed movements were produced with the same finger which was required to produce the target response, regardless of whether these observed movements were produced by a right or a left hand.

4. Experiment 1

4.1. Method

Participants performed a choice reaction-time task with a small, colored circle as the discriminative stimulus. The circle was 1 cm in
diameter, it could be blue or red, and it appeared centered on a 15.4 inch computer screen. Participants were told to identify the color of the circle, and to respond to it as fast and accurately as possible, by pressing a corresponding key with the index or the middle finger of their right hand. On each trial, a left or a right hand was displayed concurrently on the screen, and it could remain static (on the baseline trials), or could show a tapping movement produced with the index or the middle finger. Participants responded to the color-discrimination task over 10 successive blocks of 40 trials each. Blocks 1 to 4 and 6 to 9 were arranged as single-hand blocks, depicting exclusively left-hand or right-hand scenes over an entire block. Left-hand and right-hand blocks were presented in counterbalanced blocks, following an ABBA BAAB design. Blocks 5 and 10 were arranged as mixed blocks, in which both right-hand and left-hand scenes were presented at random.\(^1\)

4.1.1. Participants
Eighteen students of Psychology volunteered to take part in the experiment. All participants were right-handed, and their ages were between 19 and 21.

4.1.2. Apparatus and material
The experiment was designed with INQUISIT 3.0.4.0 software (Millisecond software, 2010), and it was run on a Toshiba M30X-166 laptop. On each trial, participants were presented with a short video-clip showing the following series of events (see Fig. 1): 1) the image of a left or a right hand presented over the upper half of the screen, protruding toward the observer, and with the fingers pointing toward the center of the screen, which remained static for 480 ms; 2) a rapid series of five photograms (5 × 40 ms), which produced the appearance of a tapping movement of either the middle or the index finger, or that remained static for another 200 ms in the baseline condition; and 3) coinciding with one of the two final frames of this photogram series (i.e., 120 or 160 ms after the onset of the movement), a small red or blue circle was presented as the discriminative stimulus, centered below the two relevant fingers, and remaining on the screen until a response was emitted. Stürmer et al. (2000) compared the effects of different delays over the automatic imitation of hand gestures, and they obtained no differences in the range between 0 and 400 ms. However, in contrast to Brass et al. (2000) or Bertenthal et al. (2006), who presented the discriminative stimulus simultaneously with the onset of the movement, we postponed the appearance of the target until a point in time in which the moving finger had almost reached its final position, so as to allow participants to perceive the movement before moving the focus of attention toward the discriminative stimulus. The use of onset asynchronies of 120 ms or 160 ms did not produce any effect on performance, and therefore we collapsed all of the trials regardless of this factor. The stimuli were video-clips digitally edited with Adobe Premiere Pro CS3. Participants were instructed to respond to the color of the circle by pressing the “n” or “m” keys of a keyboard, which were marked respectively with red and blue stickers, by using the index and middle fingers from their dominant, right hand.

4.1.3. Procedure
After preliminary instructions, the arbitrary mapping between colors and key presses was briefly trained through a practice block of 20 trials in which only the colored circles were presented. Participants were instructed to use the index finger of their right hand to press the key “n” when the circle was red, and to use the middle finger of the same hand to press the key “m” if the circle was blue. Errors were signaled by a beep, and participants were required to correct their response before proceeding to the next trial. The interval between successive trials was set to 500 ms.

The practice block was followed by 10 experimental blocks, each composed of a series of 40 trials presenting different arrangements of hands and colored circles. Within each block, six types of trials were presented at random without replacement, crossing colors (red vs. blue circle) with observed actions (baseline, spatially compatible, and spatially incompatible trials). Blocks 5 and 10, which contained trials mixing right- and left-hand video clips were discarded from the analyses. Blocks 1 to 4 and 6 to 9, which were arranged as single-hand blocks, contained video-clips showing only left-hand or right-hand movements. Notice that, as in Bertenthal et al.’s (2006) experiments, left-hand blocks blended spatial compatibility and automatic imitation effects, in that all spatially compatible trials displayed movements produced with the same finger and at the same location as the required response. In contrast, the right-hand blocks set both effects in opposition, in that the spatially compatible trials were imitatively incompatible, and vice versa. The order of right-hand and left-hand blocks was counterbalanced using an ABBA BAAB design, with half of the participants starting with each type of block. The design was therefore a 2 × 3 within-participants design with Observed-Hand and Spatial Compatibility as repeated factors. Automatic imitation effects were to be inferred from the interaction between Observed Hand and Spatial Compatibility effects.

To avoid errors growing beyond reasonable limits, error feedback was provided after each block, and participants were instructed to respond as fast as possible, without falling below 90% of correct responses.

4.2. Results
Proportion of correct responses and average reaction times (RTs) for these correct responses were assessed independently as measures of performance over the relevant blocks. To analyze whether automatic imitation exerted any influence on performance, we analyzed responses to baseline, spatially compatible and spatially incompatible trials in terms of whether this spatial effect was blended with (left-hand scenes) or opposed to (right-hand scenes) the effect of automatic imitation. Confidence level was set to \(p < .05\) for all reported effects, and Greenhouse–Geisser corrected levels of confidence were reported when necessary, even though the nominal degrees of freedom were maintained.

4.2.1. Reaction times
We removed RTs from the first trial of each block, from incorrect responses (3.3%), and from outliers, defined as those trials departing more than 3 standard deviations from the mean RTs of each participant, block and condition (1.1% of the correct responses). A repeated-measures ANOVA conducted on the mean RTs over the single-hand blocks, with Spatial Compatibility (3: spatially compatible, baseline, and spatially incompatible) and Observed Hand (2: left vs. right hand) as independent factors showed a significant effect of Spatial Compatibility, \(F(2, 34) = 18.95, \eta_p^2 = .53, p < .001\). The effect of Observed Hand did not reach significance in the analysis, \(F(1, 17) = 3.06, \eta_p^2 = .15, p = .10\). More important for our purposes, no significant interaction was found between Spatial Compatibility and Observed Hand (\(F < 1\)). Planned contrasts conducted to check the direction of the spatial compatibility effects showed that responding to compatible trials was faster than responding to either baseline trials, \(F(1, 17) = 11.93, \eta_p^2 = .41, p < .01\), or incompatible trials, \(F(1, 17) = 29.54, \eta_p^2 = .64, p < .001\), and that responding to incompatible trials were significantly slower than responding to baseline
Spatial Compatibility, $F(2, 34) = 9.09$, on the proportion of correct responses, with Spatial Compatibility and over the whole experiment. A repeated-measures ANOVA conducted than for the right-hand blocks, in which these two effects were set in opposition. When both spatial and imitation effects pushed in the same direction, the overall compatibility effects were not larger for the left-hand blocks, in which the hands were now presented on the right hemi-field, and depicted finger movements produced either above or below the midline of the monitor, instead of to the left or to the right of the screen. Weeks and Proctor (1990) reported on the existence of some spatial preferences for responding to up stimuli with a right response, and to down stimuli with a left response. However, we surmise that these orthogonal spatial compatibility effects, if they appear at all, should be weaker than those observed in Experiment 1, and thus that this procedure could allow us to observe any possible effect of automatic imitation.

### 4.2. Percentage of correct responses
Correct responses were produced on an average of 97% of the trials over the whole experiment. A repeated-measures ANOVA conducted on the proportion of correct responses, with Spatial Compatibility and Observed Hand as independent factors, showed a significant effect of Spatial Compatibility, $F(2, 34) = 9.09$, $\eta^2_p = .35$, $p < .01$, but not an effect of Observed Hand, nor a significant interaction between them ($F < 1$). As observed in Fig. 2B, the proportion of correct responses was higher for baseline and spatially compatible trials than for the spatially incompatible ones. Importantly, this difference was not larger for the right-hand blocks, in which the effect of automatic imitation was added to the spatial effect, than for the right-hand blocks, in which both effects were set in opposition.

### 4.3. Discussion
From the pattern of results obtained in this experiment, we can conclude that the differences observed between compatible and incompatible trials appeared to be completely attributable to the effect of spatial compatibility, and thus do not support the existence of an effect of automatic imitation. Indeed, the spatial compatibility effect was remarkably equivalent for the right- and left-hand blocks, despite the fact that a hypothetical automatic imitation effect should have produced an opposite impact on each of these two types of blocks. In contrast to the evidence reported by Bertenthal et al. (2006), our results indicate that when this comparison is obtained within a single experiment, over the same participants, and without including any explicit imitation block, automatic imitation does not modulate the expression of spatial compatibility effects.

### 5. Experiment 2
The results of Experiment 1 showed that spatial compatibility effects might have passed for an effect of automatic imitation in those studies which lack appropriate controls for spatial effects (Bertenthal et al., 2006; Brass et al., 2000, 2001; Iacoboni et al., 1999; Spengler et al., 2010). This may indicate that the effect of automatic imitation is absent from these familiar, key-pressing tasks, but it also can be interpreted as showing that a strong spatial effect could have masked the expression of any possible advantage obtained from the observation of a movement compatible with the required one. To further analyze this possibility, one would need to control, or at least to minimize, the impact of spatial compatibility effects, and to test whether the effects of automatic imitation could be obtained in these conditions.

In Experiment 2 we adopted an orthogonal presentation strategy, which could be useful to control for the influence of spatial compatibility effects, and which has been used before with less familiar motor tasks (Catmur & Heyes, 2011; Press, Bird, Walsh, & Heyes, 2008). Specifically, we rotated the scenes 90° clockwise, so that the hands were presented on the right hemi-field, and depicted finger movements produced either above or below the midline of the monitor, instead of to the left or to the right of the screen. Weeks and Proctor (1990) reported on the existence of some spatial preferences for responding to up stimuli with a right response, and to down stimuli with a left response. However, we surmise that these orthogonal spatial compatibility effects, if they appear at all, should be weaker than those observed in Experiment 1, and thus that this procedure could allow us to observe any possible effect of automatic imitation.

### 5.1. Method
The method was analogous to that of Experiment 1, with the exception that the irrelevant hand scenes were rotated 90° clockwise, so that they now protrude from the right side of the screen (Fig. 1B). As in Experiment 1, Blocks 5 and 10 were mixed blocks, but we will again restrict the analyses to Blocks 1 to 4 and 6 to 9, which were arranged as single-hand blocks. Half of these blocks presented a model’s right hand, with the middle finger located above the midline of the screen and the index finger appearing below the midline, while the other half presented a left hand, in which the spatial locations of these fingers appeared switched. If, according to Weeks and Proctor (1990), there is a general tendency to associate up stimuli with responses on the right-side, and down stimuli with responses on the left-side, then the right-hand blocks should be taken as the blocks producing a blend between imitative and (orthogonal) spatial compatibility effects, whereas the left-hand blocks should be considered as the blocks confronting both effects. Thus, for instance, if a trial showed a red circle requiring participants to respond with their index finger pressing the leftmost key, then observing a right hand moving the index finger at the lower part of the screen would produce both a finger imitation effect (index→index) and an orthogonal spatial compatibility effect (bottom→left). In contrast, in those blocks showing a left-hand scene, the movement of an index finger would appear at the upper part of the screen, and therefore the effect of finger imitation (index→index) will be set in opposition to an orthogonal spatial incompatibility effect (up→left).

#### 5.1.1. Participants
Another group of 18 Psychology students volunteered to take part in the experiment. All participants were right-handed, and their ages were also between 19 and 21. One participant who produced
extremely slow RTs (i.e., beyond three standard deviations from the group average) was discarded from the analyses.

5.2. Results

5.2.1. Reaction times

As in Experiment 1, we removed RTs from the first trial of each block, from incorrect responses (2.4%) and from outliers (0.6% of the correct responses). Because spatial compatibility was arguably controlled in this experiment, we used Finger correspondence (3: finger-compatible, baseline, finger-incompatible) as the main independent variable. A repeated-measures ANOVA conducted on RT with Finger Correspondence and Observed Hand as independent factors showed a significant effect of Finger Correspondence, F (2, 32) = 15.42, η²p = .49, p < .001, but not an effect of Observed Hand, nor a significant interaction between these two factors (Fs < 1). As shown in Fig. 3A, these results clearly show that RTs were affected by the Finger Compatibility between the required and the observed actions, even when the displayed movements were orthogonal to the required responses. In contrast to the spatial effects obtained in Experiment 1, responding to finger-compatible trials did not seem to produce an advantage with respect to the baseline trials in these conditions, but responding to finger-incompatible trials resulted in a significant interference. Planned contrasts confirmed these extremes, by showing a significant difference between responding to finger-incompatible trials and to finger-compatible trials, F (1, 16) = 17.53, η²p = .53, p < .001, but no difference between responding to compatible and baseline trials (F < 1). The effect of Finger Compatibility was not modulated by the observed hand (F < 1), thus indicating that the impact of an orthogonal spatial mapping was negligible under these conditions. In other words, the effect of watching an index finger movement affected participants responding with their index or middle finger, regardless of whether the observed movement was produced below the screen midline (right-hand model) or above this midline (left-hand model).

5.2.2. Percentage of correct responses

Correct responses were produced on 98% of the trials over the whole experiment (see Fig. 3B). A repeated-measures ANOVA conducted on the proportion of correct responses over the single-hand blocks, with Finger Correspondence and Observed Hand as independent factors, showed that participants responded more accurately to trials displaying a right hand than to those showing a left hand (.980 vs. .972), F (1, 16) = 6.51, η²p = .29, p < .05. The effect of Finger Correspondence just missed significance, F (2, 32) = 3.35, η²p = .17, p = .07, and there was no significant interaction between both factors (F < 1).

5.3. Discussion

Two conclusions are justified by the results of Experiment 2. First, these results indicate that the orthogonal manipulation arranged in this experiment has been useful to minimize the effects of spatial compatibility that were found in Experiment 1 and, in so doing, to reveal the existence of clear effects of automatic imitation. The analogous effects obtained for both left-hand and right-hand blocks, especially on the measures of RT, indicate that the effects of orthogonal correspondence observed by Weeks and Proctor (1990) were not affecting performance in this experiment.

Second, in contrast with the spatial effects observed in Experiment 1, the automatic imitation effects obtained in Experiment 2 seem to be exclusively due to an effect of interference, in that the observation of compatible movements did not speed performance with respect to the baseline, whereas the observation of an incompatible action incurred a significant cost in responding to these trials. Thus, at least for the conditions tested in the present experiment, the automatic imitation effects cannot be accounted for in terms of a facilitation produced in those trials requiring participants to mirror an irrelevant action, but rather as an added difficulty encountered when the observer has to perform an action that is incompatible with the observed one.

6. General discussion

The goal of this study has been to test whether it is possible to obtain automatic imitation effects in a key-pressing task when the modeled actions are task irrelevant over the whole experiment, and when these imitation effects are effectively dissociated from the effects of spatial compatibility. In Experiment 1, we adapted a procedure devised by Bertenthal et al. (2006, Experiments 1 and 2) to distinguish spatial compatibility from automatic imitation effects, by comparing conditions in which both of these effects acted either in coalition or in opposition to each other. In contrast to Bertenthal et al. (2006), we removed the imitation blocks in order to make sure that imitation was never part of the participants’ task goals, and presented left-hand and right-hand scenes to the same participants over a single experiment. The results of Experiment 1 showed that spatial compatibility effects exerted a strong influence on performance, to the point of precluding the expression of automatic imitation over these conditions.

The pattern of results obtained in Experiment 1 indicates that spatial compatibility effects could have unduly passed for automatic imitation in some previous experiments lacking appropriate controls (e.g., Brass et al., 2000, 2001; Iacoboni et al., 1999; Spengler et al., 2010). However, in order to analyze whether such automatic imitation effects could arise more clearly under conditions less affected by spatial compatibility, in Experiment 2 we presented the scenes in an orthogonal disposition with respect to the required responses. Despite previous reports showing that some spatial compatibility effects could persist even over such orthogonal arrangements (Weeks & Proctor, 1990), we found little evidence for such a translation, and instead we obtained clear effects of automatic imitation. Together, the results of these experiments show the existence of genuine effects of automatic imitation in a familiar, key-pressing task, and go beyond...
previous research in showing how these effects can be obtained in conditions fulfilling the criteria proposed by Heyes (2011), dissociating imitation from non-imitative effects.

From a methodological standpoint, these results call attention to the difficulties underlying the proper treatment of this confusion between spatial compatibility and automatic imitation effects. Even though researchers in this area have been aware of this confusion, and have dealt with it in a number of different ways (Aicken et al., 2007; Brass et al., 2001; Catmur & Heyes, 2011; Heyes, 2011; Jansson et al., 2007; Press et al., 2008), we contend that the issue had not been satisfactorily addressed to date in finger tapping tasks. A few recent studies have dealt with this confound by presenting orthogonal displays very similar to those used in the present study (Cook & Bird, 2011, 2012). However, at variance with the procedure arranged in our Experiment 2, these studies used a single video-taped hand, and therefore they implemented a single correspondence between the location of each finger movement and the location of the required response. These results, therefore, could still be accounted in terms of an orthogonal spatial correspondence, which could associate movements on the upper part of the display with responding on the right side, and vice versa (Weeks & Proctor, 1990). Indeed, in these two recent studies, the authors also reported that similar effects were obtained in conditions in which no finger movement was observed, but in which the relevant finger was highlighted with a color change. The authors termed this effect as an “effector priming effect”, but one might also claim that this effect could also have resulted from the effect of “orthogonal spatial correspondence” which was still confounded with both effector priming and automatic imitation effects. In this regard, we surmise that the use of two different hands as arranged in our Experiment 2 could be particularly useful to disentangle spatial from imitation effects.

Other attempts to distinguish between spatial and imitation effects have been based on distributional analyses of RTs. Brass et al. (2001) showed that, even though both imitation and spatial effects grew larger for slower trials, the slope of imitation effects was steeper than that found for spatial compatibility effects. However, because this alleged difference is defined exclusively in comparative terms, it is difficult to use it as a sole criterion for distinguishing between imitative and spatial effects. Jansson et al. (2007) failed to obtain such a difference in two independent experiments, and Catmur and Heyes (2011), even though they reported to have obtained a pattern consistent with Brass et al. (2001), they did not replicated this previous pattern, but rather they found growing effects for slower trials only in the imitative task, and not in the spatial task. In sum, from these results it is not clear at all which pattern of results could be taken as indicative that the effects are imitative or spatial in nature.

To ascertain whether our results could show any systematic pattern depending on whether they reflected mainly spatial or mainly imitative components, we conducted two distribution analyses for the RTs obtained in each of these two experiments, grouping all RT in five bins depending on their relative speed. A repeated-measures ANOVA on these RTs for Experiment 1, with Observed Hand (2), Spatial Compatibility (2, compatible and incompatible) and Quintile (5) as independent variables, showed neither a significant Spatial Compatibility × Quintile interaction, $F(4, 68) = 1.12, r^2 = .06, p > .31$ nor a significant three-way interaction, $F(4, 68) = 1.21, r^2 = .07, p > .29$. Thus, consistently with the results reported by Catmur and Heyes (2011) for the spatial compatibility effects, in Experiment 1 we did not find any tendency of the effect of compatibility to grow larger for slower RTs. Interestingly, a similar distribution analysis conducted for Experiment 2, in which Compatibility effects referred specifically to finger correspondence, showed a significant Imitative Compatibility × Quintile interaction, $F(4, 68) = 12.85, r^2 = .45, p < .001$. This interaction showed that the effect of Finger Compatibility grew larger for slower RTs, reaching average values of 14, 18, 22, 32, and 68 ms, respectively, for quintiles one to five. Together, the results reported in these two distributional analyses are consistent with those reported by Catmur and Heyes (2011), and with the general claim that automatic imitation effects increase more for slower RTs than do spatial compatibility effects (Brass et al., 2001). Moreover, these results provide further support to the claim that in Experiment 1 the observed compatibility effects were essentially spatial, while in Experiment 2 the effects were imitative. An intriguing hypothesis could assume that, if automatic imitation effects accrue slower than did spatial compatibility effects, then the use of spatial information could have left no room for the expression of imitative effects. This hypothesis is consistent with the overall faster RTs observed in Experiment 1, but it will not account for the absence of imitative effects observed in this experiment for those trials in which the spatial information was not valid. In sum, the results show that both effects are functionally dissociable, but that they could be confounded, especially when the scenes are presented as from a mirror perspective.

As a case illustrating this potential confound, it may be worth considering a recent study by Spengler et al. (2010), in which the authors aimed at assessing automatic imitation in people with autism spectrum conditions (ASC). These authors presented participants with irrelevant video-clips showing a finger movement from a mirror perspective, and they found that the ASC group was more prone to produce errors in incongruent trials, and that they showed a tendency to produce larger effects of interference in the measures of RT. The authors interpreted these results as showing “experimental evidence for the hyper-imitation of actions in adults with ASC” (p. 1154). However, given that spatial compatibility effects were not clearly distinguished from imitation effects in these conditions, it is equally plausible to interpret the differences obtained between these groups as related to an increase in the effects of spatial compatibility, which might also be caused by the executive dysfunction often observed in people with ASC (Hill, 2004).

Finally, from a theoretical perspective, the differences observed between the two experiments reported in the present study might offer some additional hints on the distinction between spatial compatibility and automatic imitation effects. Even though a comparison between two independent experiments should be taken with caution, and requires further confirmatory research, the results point to the existence of differences between spatial and imitative effects, not only with respect to their respective time courses, but also concerning their facilitative vs. interference components. Comparisons of performance on compatible and incompatible trials against their proper baselines suggest that the spatial effects obtained in Experiment 1 may reflect a combination between facilitative and interference effects, in that RTs to baseline trials were roughly in between those produced in response to compatible and incompatible trials. In contrast, the automatic imitation effects observed in Experiment 2 appeared to be based exclusively on an effect of interference, because responding was not faster for compatible trials than for baseline trials, but there was a significant cost associated to responding to incompatible trials. The difference between spatial and imitative effects in terms of their facilitative vs. interference components could be seen as consistent with a general suggestion made by Brass, Ruby, and Spengler (2009), who claimed that, if the mere observation of an action activates its motor representation as a tool to understand its meaning, then this tendency should become compensated by a default inhibitory mechanism which avoids the overt reproduction of all observed actions. According to this reasoning, and also in agreement with some connectionist modeling approaches to the distinction between spatial and imitative compatibility effects (Boyer, Scheutz, & Bertenthal, 2009; Saussier & Billard, 2006), inhibitory mechanisms might play a more prominent role in the regulation of imitative processes than in the regulation of spatial compatibility effects, especially when the actions are well-practiced, simple, and familiar. Unfortunately, without a larger number of studies including baseline trials,
as well as control procedures to separate spatial from imitation effects, it will not be possible to reach a clear conclusion on whether automatic imitation effects are facilitatory or inhibitory in nature. We surmise that the use of orthogonal preparations such as the one illustrated in the present study could help us in clarifying these theoretically important issues.

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