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Spatial Parameters at the Basis of Social Transfer of Learning

Luisa Lugli
University of Modena and Reggio Emilia and University of Bologna

Cristina Iani and Nadia Milanese
University of Modena and Reggio Emilia

Natalie Sebanz
Central European University

Sandro Rubichi
University of Modena and Reggio Emilia

Recent research indicates that practicing on a joint spatial compatibility task with an incompatible stimulus-response mapping affects subsequent joint Simon task performance, eliminating the social Simon effect. It has been well established that in individual contexts, for transfer of learning to occur, participants need to practice an incompatible association between stimulus and response positions. The mechanisms underlying transfer of learning in joint task performance are, however, less well understood. The present study was aimed at assessing the relative contribution of 3 different spatial relations characterizing the joint practice context: stimulus-response, stimulus-participant, and participant-response relations. In 3 experiments, the authors manipulated the stimulus-response, stimulus-participant, and response-participant associations. We found that learning from the practice task did not transfer to the subsequent task when during practice stimulus–response associations were spatially incompatible and stimulus-participant associations were compatible (Experiment 1). However, a transfer of learning was evident when stimulus-participant associations were spatially incompatible. This occurred both when response-participant associations were incompatible (Experiment 2) and when they were compatible (Experiment 3). These results seem to support an agent corepresentation account of correspondence effects emerging in joint settings since they suggest that, in social contexts, critical to obtain transfer-of-learning effects is the spatial relation between stimulus and participant positions while the spatial relation between stimulus and response positions is irrelevant.

Keywords: social cognition, joint performance, spatial compatibility, Simon effect, social transfer-of-learning

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Researchers in the field of cognition have recently started to devote more attention to the processes involved in social interactions. The adoption of a social perspective starts from the assumption that social cognition could not be fully understood by focusing only on single individuals (e.g., Galantucci & Sebanz, 2009). With regard to joint actions in perceptual-motor tasks, for example, there is clear evidence that action planning of one agent includes also the action that is performed by the other agent. One of the first demonstrations of this was provided by Sebanz and colleagues (Sebanz, Bekkering, & Knoblich, 2006; Sebanz, Knoblich, & Prinz, 2003) by means of the social variant of the Simon task.

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Luisa Lugli, Department of Communication and Economics, University of Modena and Reggio Emilia, and Department of Philosophy and Communication, University of Bologna; Cristina Iani and Nadia Milanese, Department of Communication and Economics, University of Modena and Reggio Emilia; Natalie Sebanz, Department of Cognitive Science, Central European University; Sandro Rubichi, Department of Communication and Economics, University of Modena and Reggio Emilia.

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Correspondence concerning this article should be addressed to Cristina Iani or Sandro Rubichi, Department of Communication and Economics, University of Modena and Reggio Emilia, Via Allegri 9, 42121 Reggio Emilia, Italy. E-mail: cristina.iani@unimore.it or sandro.rubichi@unimore.it

In the individual version of the Simon task, participants are instructed to press a left or right key according to stimulus color. The stimulus can appear either to the right or to the left of a central fixation point; hence trials can be either corresponding (i.e., stimulus and response positions are ipsilateral) or noncorresponding (i.e., stimulus and response positions are contralateral). Even though stimulus location is task-irrelevant, response times (RTs) are shorter and accuracy is higher in corresponding than in noncorresponding trials. The advantage for corresponding trials (i.e., the Simon effect) demonstrates the influence of irrelevant spatial information (stimulus location) on performance (Simon & Rudell, 1967; Rubichi & Nicoletti, 2006; Rubichi, Nicoletti, Iani, & Umiltà, 1997; Rubichi, Nicoletti, Pelosi, & Umiltà, 2004; for reviews, see Proctor & Vu, 2006; Rubichi, Vu, Nicoletti, & Proctor, 2006).

In the social variant of the Simon task, two participants perform the task together, so that each participant is performing a go/no-go task: One participant is instructed to press the left key in response to green stimuli and the other is instructed to press the right key in response to red stimuli. To note, the Simon effect does not typically arise when a single participant performs the go/no-go task alone (e.g., Sebanz et al., 2003; see also Lugli, Iani, Nicoletti, & Rubichi, 2013). The observation of a social Simon effect has been taken as evidence that participants tend to represent the coactor's

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task and to integrate their own and the other's task into a common representation even though each participant is responsible for only half of the task and hence for only one response alternative (cf. Sebanz et al., 2003; see also Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011; Ferraro et al., 2012; but see Dittrich, Dolk, Rothe-Wulf, Klauer, & Prinz, 2013; Dolk, Hommel, Prinz, & Liepelt, 2013; Sellaro, Treccani, Rubichi, & Cubelli, 2013 for a different interpretation).

In line with this social perspective, researchers have recently begun to investigate not only how and to what extent sharing a task with another person influences individual performance but also how acting alongside another person influences learning processes (Milanese, Iani, & Rubichi, 2010; Milanese, Iani, Sebanz, & Rubichi, 2011; Ferraro et al., 2012). Indeed, during social interactions we may acquire knowledge that could then be used in other situations. Hence, it becomes relevant to understand whether and how jointly practiced task rules modulate subsequent performance. As regards individual performance in perceptual-motor tasks, the way in which knowledge acquired in a task can be transferred to and affects the way a subsequent task is performed has been extensively studied by means of the transfer-of-learning (ToL) paradigm, originally developed by Proctor and Lu (1999; see also Iani, Rubichi, Gherri, & Nicoletti, 2009; Iani, Rubichi, Ferraro, Nicoletti, & Gallese, 2013; Pellicano et al., 2010; Vu, 2007). In this paradigm participants are required to practice with a spatial compatibility task with an incompatible stimulus-response (S-R) mapping (i.e., they are instructed to press a right key when a stimulus appears on the left and a left key when a stimulus appears on the right). This task is followed by a Simon task in which stimulus location is irrelevant and responses have to be made on the basis of a nonspatial stimulus feature (e.g., color).

Studies that have used the ToL paradigm have consistently found that, after practicing with a spatially incompatible mapping between stimuli and responses, the standard Simon effect is reduced, eliminated, or even reversed (ToL effect). The ToL effect is thought to rely on the fact that the noncorresponding S-R associations acquired during the practice task remain active and influence performance in the subsequent Simon task. Hence, the modulation of the standard Simon effect by a previous incompatible spatial compatibility practice demonstrates that individual performance depends not only on the goals of the task that is currently being performed, but also on immediate prior experience.

Starting from this evidence, Milanese et al. (2010) adapted the ToL paradigm used in individual contexts to a joint context. In their social version of the paradigm (from now on, social transfer of learning paradigm or SToL paradigm), two participants performed the spatial compatibility task (practice task) together, followed by the Simon task (transfer task). They found that S-R associations acquired during the joint spatial compatibility task remained active and transferred to the joint Simon task leading to an elimination of the joint Simon effect. In contrast, S-R associations acquired in the joint spatial compatibility task did not transfer to individual Simon task performance. In other words, the SToL effect emerged only when both practice and transfer tasks took place in a social setting, suggesting that participants did not only transfer what was specifically acquired during practice, but also aspects of the interactive context in which learning took place.

In a follow-up study, Milanese et al. (2011) further investigated which elements of the joint context needed to remain constant for transfer between a jointly performed practice task and a subsequent joint transfer task to occur. In two experiments they assessed the relevance of two aspects of the social context: the identity of the coactor and the spatial relation of the two actors. Results showed that a spatially incompatible practice performed jointly with another agent influenced performance on a subsequent joint Simon task even if the coactor's identity changed, whereas when participant's position changed from the practice to the transfer task (i.e., the participant sitting on the left in the practice session moved to the right in the transfer session, while the opposite was true for the other participant), the SToL effect did not emerge. Hence, the identity of the coactor was not crucial; what mattered was the overlap between the spatial relations of the practice and transfer tasks experienced by a given participant.

Although these results clearly point to the importance of the spatial relations experienced during the practice task, it is unknown which specific spatial relations are really crucial to obtain the modulation of performance on the subsequent joint Simon task. In the individual version of this task it is clear that participants need to practice an incompatible association between stimulus and response positions to obtain transfer of learning effects. However, in the joint condition, another set of right-/left-defined parameters is present, because participants are sitting on the right or on the left relative to their coagent (Welsh, 2009). Thus, not only the response may be compatible or incompatible with respect to stimulus position, but also the participant's sitting position. More precisely, in the standard version of the SToL paradigm, during a spatially incompatible practice, in which participants are required to respond to contralateral stimuli, the position of the agent spatially corresponds with the position of the response and both are always spatially incompatible with respect to stimulus position (see Figure 1). Obviously, the position of the response refers to the right/left button location on the keyboard, and the participant's position refers to the left/right displacement of the participant's body with respect to the center of the display. Thus, it is not possible to assess

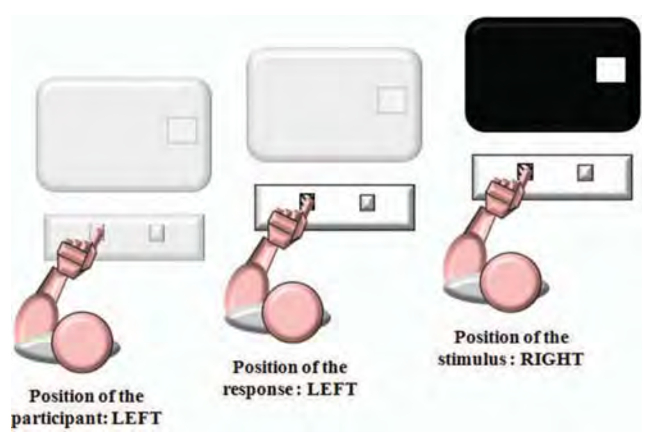

Figure 1. Schematic representation of the spatial relations among the stimulus, the response key and the responding agent in the standard social transfer of learning paradigm. For clarity, only one agent in the pair is depicted. During the incompatible practice, the position of each agent coincides with the response location and both are always spatially incompatible with respect to stimulus location. See the online article for the color version of this figure.

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which of the two incompatible relations is fundamental to obtain the SToL effect and, as a consequence, it is not possible to assess whether performance in the social Simon task is completely comparable to performance in the individual condition. This issue becomes particularly relevant if one considers the different accounts that have been proposed to explain the social Simon effect (see Wenke et al., 2011, for a review). According to the task/action corepresentation account (e.g., Sebanz et al., 2006), in a joint action context, participants represent their coactor's task as if it was their own, including the other agent's S-R mapping in their own representation of the task. Hence, the social Simon effect, as the individual Simon effect, is seen as the result of response conflict. Differently, according to the agent corepresentation account proposed by Wenke et al. (2011), participants in joint task settings represent that another person is responsible for the complementary part of the task and when the other person has to respond. According to this account, a stimulus on the right does not prime the right response but rather primes the coactor sitting on the right. The social Simon effect is hence the result of a conflict concerning agent discrimination and identification of whose turn it is. These two accounts lead to different predictions on which spatial relation practiced during a prior task can affect subsequent performance on a social version of the Simon task. Indeed, because for the task corepresentation account, S-R associations are responsible for the social Simon effect, performance on this task should be affected by prior practice with a spatial incompatible S-R mapping. On the contrary, since for the actor corepresentation account, stimulus-participant (S-P) associations are responsible for the social Simon effect, performance on this task should be affected by prior practice with a spatial incompatible S-P mapping.

Given the considerations reported above, the aim of the present study was to investigate which spatial relations acquired during a joint practice affect subsequent performance in the social Simon effect. In particular, we aimed at disentangling the effect of prior practice with a spatially incompatible S-R relation from the effect of prior practice with a spatially incompatible S-P relation. To this aim, in two experiments, participants were required to perform a joint practice with crossed hands, so that the participant response (P-R) association was always incompatible, before performing a joint Simon task with uncrossed hands. In the practice session of Experiment 1, the S-R associations were spatially incompatible, whereas the S-P associations were spatially compatible. This was achieved by requiring participants to respond to the stimulus that was contralateral with respect to the position of the response with their arms crossed (i.e., for instance, the participant sitting on the left responded by pressing the right key in response to the left stimulus). In the practice session of Experiment 2, the S-P associations were spatially incompatible, whereas the S-R associations were spatially compatible. This was achieved by requiring participants to respond to the stimulus that was contralateral with respect to their sitting position with their arms crossed (i.e., for instance, the participant sitting on the left responded by pressing the right key in response to the right stimulus). In both experiments, the P-R relation was always incompatible. In a third experiment we required participants to respond to the stimulus that was contralateral with respect to their sitting position with their arms uncrossed (i.e., for instance, the participant sitting on the left responded by pressing the left key in response to the right stimulus). In this way, both S-R and S-P associations were spatially incompatible, whereas P-R associations were spatially compatible.

Starting from the evidence that in individual contexts what is learnt and transferred to the subsequent Simon task is the incompatible S-R incompatible association, we hypothesized that, if the individual and social tasks can be considered as comparable, the STOL effect should emerge following practice with an incompatible S-R mapping. Hence, the SToL effect should be present in Experiment 1 and absent in Experiment 2. On the contrary, if in social contexts the S-P relation is more relevant, then the SToL effect should be present in Experiment 2 and absent in Experiment 1. The observation of a STOL effect in Experiment 3 would provide further evidence of the crucial role of S-P relations. The absence of the SToL effect in all three experiments would suggest that both S-R and S-P spatial relations play a crucial role in social contexts.

In addition, in Experiments 1 and 2 we also tested the relative importance of stimulus, response, and participant locations by asking half of the participants to switch position between the practice and the transfer sessions. In other words, if during the compatibility task Participant A was seated on the right and Participant B was seated on the left, during the Simon task they switched sitting positions and were asked to use the alternative hand to press the same response key used in the practice session. This manipulation allowed us to assess whether for the SToL effect to occur the same response key has to be used across practice and transfer tasks.

Experiment 1

The present experiment was aimed at assessing whether the SToL effect emerges when participants practice an incompatible S-R association, whereas the S-P association is compatible. To this aim, in the practice task, each participant in the pair was required to respond to stimuli that appeared on his or her side (compatible S-P association) by pressing the response key that was contralateral relative to his or her sitting position (incompatible S-R association). In the transfer task, participants were administered a joint Simon task in which they responded to only one stimulus color by pressing the key at their disposal with uncrossed hands.

Two conditions were included—in the nonswitch condition each participant kept the same position and responded with the same hand across practice and transfer tasks. As a consequence of this, the position of the response button changed from the practice to the transfer task (see Figure 2, top left panel); in the switch condition participants switched sitting position and responded with the alternative hand. As a consequence of this, the position of the response remained constant across practice and transfer tasks, but the participant's position changed (see Figure 2, top right panel).

If it is the incompatibility of the S-R association acquired during practice that is crucial, in the nonswitch condition we should find a SToL effect. It is, however, possible that the STOL effect does not emerge in this condition because the position of the response button changes from the practice to the transfer task. Introducing the switch condition can allow us to assess whether using the same response key across the practice and the transfer tasks leads to the elimination of the joint Simon effect after practicing a spatially incompatible S-R association. If a regular joint Simon effect emerges in both conditions, we can conclude that the S-R incom-

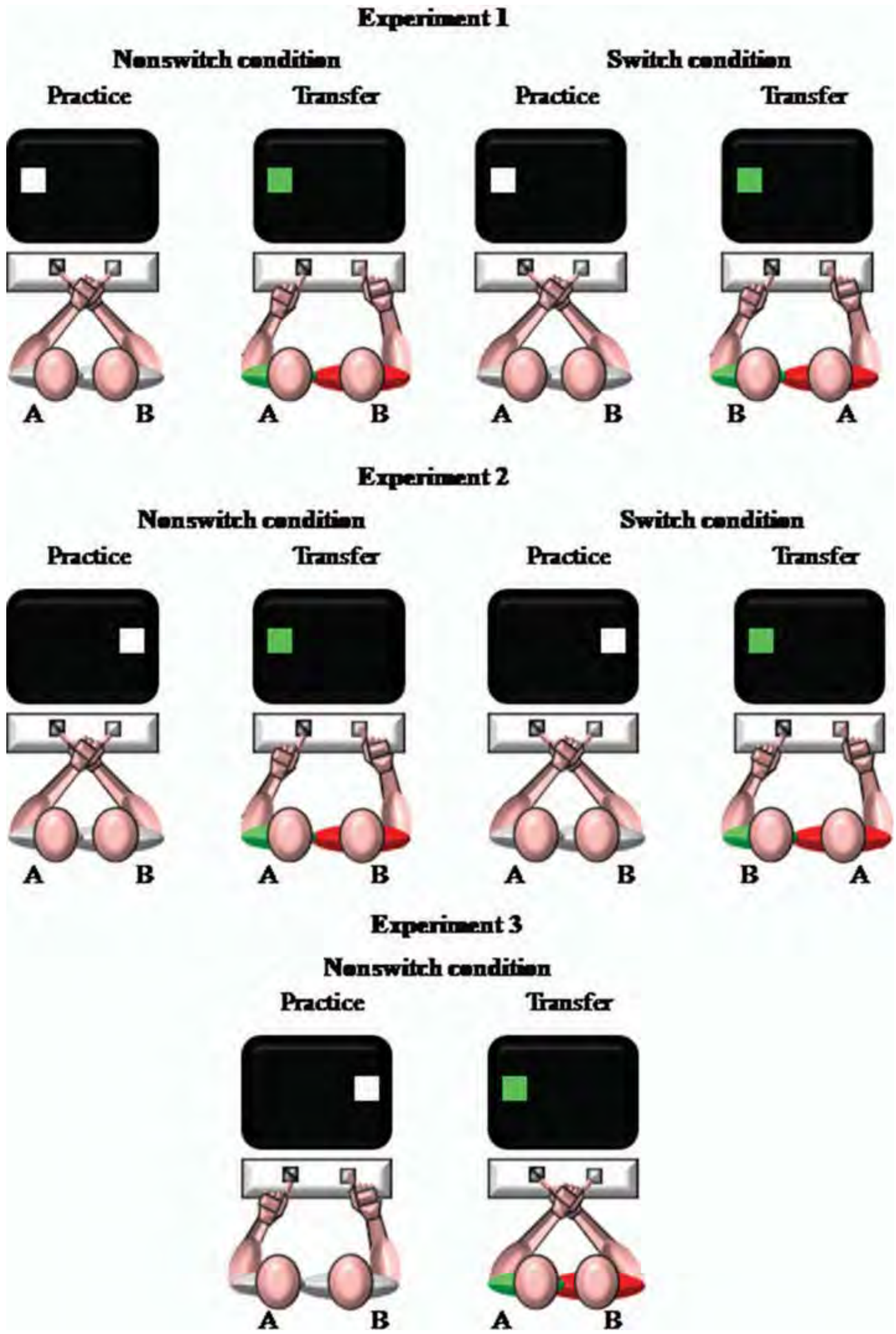

Figure 2. Schematic representation of the experimental conditions used in the three experiments. In Experiments 1 and 2, in the practice session, the participant sitting on the left (A) was required to press the right key in response to the left stimulus (participant-response [P-R] and stimulus-response [S-R] associations were spatially incompatible and the stimulus-participant [S-P] association was compatible, Experiment 1) or to the right stimulus (P-R and S-P associations were spatially incompatible and the S-R association was compatible, Experiment 2). In both experiments, in the nonswitch condition, each participant kept the same sitting position across practice and transfer sessions, while the position of the response changed (see left panel). In the switch condition, participants switched position and responding hand from the practice to the transfer session, while the position of the response remained the same (see right panel). In Experiment 3, in the practice session, the participant sitting on the left (A) was required to respond by pressing the left key in response to the right stimulus. In the transfer session, the participant on the left (A) was required to respond by pressing the right key. See the online article for the color version of this figure.

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patible association learned in the practice task does not affect subsequent Simon task performance.

Method

Participants. Thirty-two undergraduate students (one male; four left-handed; age range: 19–26 years) participated for partial fulfillment of course credit. All reported normal or corrected-to-normal vision and were naïve as to purpose of the study. Once recruited, participants were randomly paired and each pair was randomly assigned in equal proportions to one of two experimental conditions (i.e., nonswitch and switch conditions).

Apparatus and stimuli. As in Milanese et al. (2010, 2011), stimuli in the spatial compatibility task were white solid squares (4.5 × 4.5 cm), whereas stimuli in the Simon task were red or green solid squares (4.5 × 4.5 cm). All stimuli were presented on a black screen, 9.5 cm to the left or to the right of a central fixation cross (1 × 1 cm). Stimulus presentation and response collection were controlled by an IBM computer running E-prime (version 2) software system. In both tasks, responses were executed by pressing the "z" or "-" keys of a standard Italian keyboard with the left or right index finger, respectively. Viewing distance was about 60 cm.

Procedure. The experiment consisted of two consecutive sessions, a practice session and a transfer session performed jointly, separated by a 5-min interval. In the practice session participants' hands were crossed so that the participant sitting on the left pressed the response key located on the right with his or her left hand and the participant sitting on the right pressed the response key located on the left with his or her right hand. In the transfer session, the hands were uncrossed.

In the practice session participants performed a joint spatial compatibility task with an incompatible S-R mapping (i.e., stimulus position was mapped incompatibly to response position, that is, participants were required to respond to the contralateral stimulus with respect to the response position). Each participant was instructed to respond to only one of the two stimulus locations by pressing the contralateral key and to refrain from responding when a stimulus appeared in the alternative position. Hence, half of the participants responded to left stimuli by pressing a right key, whereas the other half responded to right stimuli by pressing a left key.

In the transfer session, participants were administered a joint Simon task in which they responded to red and green stimuli while stimulus location was always irrelevant. Participants were instructed to respond to only one stimulus color by pressing the key at their disposal. For half of the participants, the participant on the right was required to press the right key in response to red stimuli while the participant on the left was required to press the left key in response to green stimuli. For the other half, the participant on the right was required to press the right key in response to green stimuli while the participant on the left was required to press the left key in response to red stimuli.

In the nonswitch condition, each participant kept the same sitting position across practice and transfer tasks, while the response position changed. That is, for instance, the participant sitting on the left and pressing the right key with the left hand in the practice session, in the transfer session sat on the left and pressed the left key with the left hand (see Figure 2, top left panel). In the switch condition, in the transfer session participants switched sitting position and performed the transfer task using the alternative hand, while response position was kept constant. That is, for instance, the participant sitting on the left and pressing the right key with the left hand in the practice session, in the transfer session sat on the right and pressed the right key with the right hand (see Figure 2, top right panel).

In both tasks, a trial began with the presentation of the fixation cross at the center of a black background. After 1000 ms the stimulus appeared to the left or to the right of fixation. In the spatial compatibility task, the stimulus remained visible for 600 ms, and the maximum time allowed for a response was 1200 ms. In the Simon task, the stimulus remained visible for 800 ms and the maximum time allowed for a response was 1000 ms. These presentation times were chosen to allow for a comparison with the results of previous studies assessing transfer of learning in social contexts (Milanese et al., 2010, 2011). The response terminated the trial and the inter-trial-interval was 1 s.

The spatial compatibility task was composed of 12 training trials and 300 experimental trials that were divided into three blocks of 100 trials each. The Simon task consisted of 12 training trials and 160 experimental trials that were divided into two blocks of 80 trials each. For both tasks, instructions stressed both speed and accuracy of performance. No feedback was provided.

Results and Discussions

Spatial compatibility task. Errors were 0.5% and 0.4% in the nonswitch and switch conditions, respectively. Correct RTs were entered into a repeated-measures analysis of variance (ANOVA) with block (1 to 3) as within-subject factor, and participant's position (right vs. left) and condition (nonswitch vs. switch) as between-subjects factors. The respective data are shown in Table 1, top panel.

Neither the main effects nor the interactions were significant, Fs < 1.5, ps $> .24$, η_p^2s $< .05$.

Simon task. Errors were 1.3% and 1.9% in the nonswitch and switch conditions, respectively. Correct RTs and arcsine-transformed error rates (ERs) were submitted to two separate repeated-measures ANOVAs with Correspondence (corresponding vs. noncorresponding trials) as within-subject factor and Condition (nonswitch vs. switch) as between-subjects factor. The respective data are shown in Table 2, top panel.

The analysis on RTs revealed a main effect of correspondence, with faster responses in corresponding (332 ms) than in noncorresponding (349 ms) trials, $F(1, 30) = 27.32$, $MSE = 170.26$, $p < .001$, $\eta_p^2 = .477$. The effect of condition did not reach significance, $F < 1$, $p = .84$, $\eta_p^2 = .001$. The Simon effect was present in both conditions, as indicated by the lack of a significant interaction between correspondence and condition, $F(1, 30) = 2.08$, $p = .16$, $\eta_p^2 = .065$. Because the effect was numerically larger in the nonswitch (22 ms) than in the switch (12 ms) condition, we performed a t test for independent samples to compare the two effects. This analysis confirmed that they did not differ, $t(1,30) = 1.443$, $p = .16$.

The error analysis revealed a main effect of correspondence, with higher ERs for noncorresponding (2.3%) than for corresponding (0.7%) trials, $F(1, 30) = 10.22$, $MSE = .008$, $p < .05$, $\eta_p^2 = .254$. The main effect of condition was not significant, $F < 1$, $p =$

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Table 1
Mean Reaction Time (in ms) and Standard Deviation for the Practice Sessions of Experiments 1, 2, and 3 as a Function of Transfer Condition (Nonswitch and Switch; Experiments 1 and 2 Only), Participant's Position, and Block

Condition	Participant's position	Block	*M*	*SD*
Experiment 1: Practice session				
Before the nonswitch condition	Right	1	320	35.8
		2	327	51.2
		3	327	50.3
	Left	1	314	38.2
		2	333	44.3
		3	315	24.7
Before the switch condition	Right	1	314	32.6
		2	321	44.3
		3	321	36.9
	Left	1	313	46.1
		2	309	50.7
		3	306	44.6
Experiment 2: Practice session				
Before the nonswitch condition	Right	1	290	40.6
		2	295	43.4
		3	300	39.1
	Left	1	280	33.4
		2	289	38.3
		3	293	25.8
Before the switch condition	Right	1	310	31.0
		2	305	27.8
		3	318	20.9
	Left	1	283	22.4
		2	299	29.5
		3	299	34.5
Experiment 3: Practice session				
	Right	1	287	46.9
		2	291	41.3
		3	289	36.0
	Left	1	276	42.5
		2	280	37.4
		3	289	48.7

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.587, $\eta_p^2 = .010$. The interaction between correspondence and condition was significant, $F(1, 30) = 4.076$, $MSE = .008$, $p = .05$, $\eta_p^2 = .12$. Fischer's LSD post hoc tests showed that in the nonswitch condition, errors were higher in noncorresponding than in corresponding trials ($p < .05$). No difference was evident in the switch condition ($p = .24$).

Hence, prior practice with a spatially incompatible S-R association did not affect subsequent Simon task performance both for the nonswitch and switch conditions. Because the S-P spatial association was compatible, the next experiment was designed to see whether this association is crucial for SToL effects to occur.

Experiment 2

The present experiment was aimed at testing the prediction that a SToL effect emerges when the practice involves an incompatible S-P association. To this end, in the practice task, each participant in the pair was required to respond to contralateral stimuli by pressing the response key that was contralateral relative to his or her sitting position. In this way, S-R associations were always spatially compatible, whereas S-P ones were always incompatible.

As in Experiment 1, two conditions were included—in the nonswitch condition each participant kept the same sitting position across practice and transfer tasks, whereas the position of the response changed (see Figure 2, middle left panel); in the switch condition, participants switched their sitting position in the transfer task and changed their response hand while response position remained constant (see Figure 2, middle right panel). This manipulation will allow us to assess whether the response key needs to be constant across practice and transfer tasks for the transfer of learning effect to emerge.

Method

Participants. Thirty-two new undergraduate students (all female; all right-handed; age range 19–20 years), selected as in the previous experiment, took part in Experiment 2. Once recruited, participants were randomly paired and each pair was randomly assigned in equal proportions to one of two experimental conditions (i.e., nonswitch and switch).

Apparatus, stimuli, and procedure. Apparatus and stimuli were the same as in Experiment 1, whereas the procedure varied as follows. During the practice task, stimulus position was mapped incompatibly to the participant's seating position (i.e., participants were required to respond to stimuli that appeared on the contralateral side with respect to their seating position). Because partici-

Table 2
Mean (Standard Deviation) Reaction Time (in ms) and ER (in %) for the Transfer Sessions of Experiments 1, 2, and 3 as a Function of Condition (Nonswitch and Switch; Experiments 1 and 2 Only), and Stimulus-Response Correspondence (Corresponding and Noncorresponding Trials)

	Nonswitch condition		Switch condition			
	M	% *ER*	*M*	% *ER*	*M*	% *ER*
Experiment 1: Transfer session						
Corresponding	328 (34.8)	0.2 (0.6)	335 (26.1)	1.3 (1.8)		
Noncorresponding	350 (34.7)	2.5 (2.2)	347 (33.4)	2.2 (3.5)		
Simon effect	22*	2.3*	12*	0.9		
Experiment 2: Transfer session						
Corresponding	316 (32.9)	0.8 (2.0)	317 (32.3)	0.9 (1.5)		
Noncorresponding	319 (27.9)	1.6 (2.4)	335 (40.1)	3.1 (3.2)		
Simon effect	3	0.8	18*	2.2		
Experiment 3: Transfer session						
Corresponding					326 (32.8)	1.3 (1.6)
Noncorresponding					334 (41.1)	1.7 (2.4)
Simon effect					8	0.4

Note. The Simon effect is computed by subtracting reaction times (RTs) and error rates (ERs) in corresponding trials from RTs and ERs in noncorresponding trials. Asterisks denote significant differences.

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pants' hands were crossed, response position and stimulus position were always spatially compatible. Each participant was instructed to respond to only one of the two stimulus locations by pressing the contralateral key and to refrain from responding when a stimulus appeared in the alternative position.

In the nonswitch condition, each participant kept the same position in both practice and transfer tasks, whereas the position of the response changed. That is, for instance, the participant sitting on the left and pressing the right key with the left hand in the practice session, pressed the left key with the left hand in the transfer session (see Figure 2, middle left panel). In the switch condition, after the practice session, participants switched sitting position and performed the transfer task using the alternative hand as compared to the practice session, but maintained the same response position. That is, for instance, the participant sitting on the left and pressing the right key with the left hand in the practice session, sat on the right and pressed the right key with the right hand in the transfer session (see Figure 2, middle right panel).

Results and Discussion

Spatial compatibility task. Errors were 0.3% and 0.4% in the nonswitch and switch conditions, respectively. Correct RTs were submitted to a repeated-measures ANOVA with block (1 to 3) as within-subject factor and participant's position (right vs. left) and condition (nonswitch vs. switch) as between-subjects factors. The respective data are shown in Table 1, middle panel.

The main effect of the block was significant, $F(2, 56) = 3.246$, $MSE = 336.738$, $p < .05$, $\eta_p^2 = .104$. Fischer's LSD post hoc tests confirmed that RTs were longer in Block 3 (302 ms) than in Block 1 (291 ms; $p < .05$). No other difference was significant. No other main effect or interaction reached significance, $p\text{s} > .25$.

Simon task. Errors were 1.2% and 2.0% for the nonswitch and switch conditions, respectively. Correct RTs and arcsine-transformed ERs were submitted to two separate repeated-measures ANOVAs with correspondence (corresponding vs. noncorresponding trials) as within-subject factor and condition (nonswitch vs. switch) as between-subjects factor. The respective data are shown in Table 2, middle panel.

The analysis on RTs revealed a main effect of correspondence, with faster responses in corresponding (316 ms) than in noncorresponding (327 ms) trials, $F(1, 30) = 18.54$, $MSE = 106.46$, $p < .001$, $\eta_p^2 = .382$. The main effect of the condition was not significant, $F < 1$, $p = .45$, $\eta_p^2 = .019$. Importantly, the Correspondence × Condition interaction was significant, $F(1, 30) = 9.03$, $MSE = 106.46$, $p < .01$, $\eta_p^2 = .231$. Fischer's LSD post hoc tests confirmed that the difference between corresponding and noncorresponding responses (i.e., the Simon effect) was significant in the switch condition (18 ms, $p < .001$) but not in the nonswitch condition (3 ms, $p = .37$).

The error analysis revealed a main effect of correspondence, with higher ERs in noncorresponding (2.3%) than in corresponding (0.9%) trials, $F(1, 30) = 7.376$, $MSE = .009$, $p < .05$, $\eta_p^2 = .197$. Neither the main effect of condition, $F < 3$, $p = .11$, $\eta_p^2 = .084$, nor the interaction between correspondence and condition were significant, $F(1, 30) = 1.161$, $p = .29$, $\eta_p^2 = .037$.

The lack of a significant Simon effect in the nonswitch condition is indicative of SToL and strongly suggests that S-P spatial incompatibility is critical for the occurrence of transfer effects, whereas the spatial association between stimulus and response appears to be irrelevant.

Experiment 3

The results of Experiment 2 indicate that, in a joint context, what is learned and transferred to a following joint Simon task is the association between stimulus position and participant position. If this is true, as long as participants practice an incompatible association between stimulus position and participant position, the STOL effect should emerge, even though other aspects of the joint task context change. To test this prediction, we ran an additional experiment in which participants in the joint practice session were required to respond with uncrossed hands to stimuli that were on the opposite side with respect to their sitting position (S-P incompatible association). In the joint transfer task, they were required to respond with their hands crossed. With this manipulation, we were able to manipulate S-R and S-P associations while the P-R association, differently from the previous two experiments, was compatible (see Figure 2, bottom panel)[1].

Method

Participants. Sixteen new undergraduate students (one male; all right-handed; age range 18–24 years), selected as in the previous experiments, participated. Once recruited, they were randomly paired.

Apparatus, stimuli, and procedure. Apparatus and stimuli were the same as in Experiment 2, whereas the procedure varied as follows. During the practice task, stimulus position was mapped incompatibly to the participant's seating position; that is, participants were required to respond to stimuli that appeared on the contralateral side with respect to their seating position. The participants' hands were uncrossed, so that, differently from Experiment 2, response position and stimulus position were always spatially incompatible. Each participant was instructed to respond to only one of the two stimulus locations by pressing the ipsilateral key and to refrain from responding when a stimulus appeared in the alternative position.

In transfer session, each participant kept the same position, while, because the crossed hand placement was required, the position of the response changed. That is, for instance, the participant sitting on the left and pressing the left key with the left hand in the practice session pressed the right key with the left hand in the transfer session.

Results and Discussion

Spatial compatibility task. Errors were 0.2% of the total trials. Correct RTs were submitted to an ANOVA with block (1 to 3) as within-subject factor and participant's position (right vs. left) as between-subjects factor. The respective data are shown in Table 1, bottom panel.

No main effect or interaction reached significance, Fs < 1.4, ps $> .28$, η_p^2s $< .088$.

Simon task. Errors were 1.5% of the total trials. Correct RTs and arcsine-transformed ERs were submitted to two separate repeated-measures ANOVAs with correspondence (corresponding vs. noncorresponding trials) as within-subject factor. The respective data are shown in Table 2, bottom panel.

RTs and errors did not differ between corresponding (326 ms; 1.3%) and noncorresponding (334 ms; 1.7%) trials, as indicated by the lack of a main effect of correspondence in both RTs, $F(1, 15) = 1.97$, $MSE = 277.14$, $p = .18$, $\eta_p^2 = .116$, and ERs, $F(1, 15) < 1$.

The results of this experiment provide confirming evidence that the incompatible S-P association is what is acquired in the practice task. They also indicate that, as long as participants practice an incompatible association between stimulus position and participant position, the STOL effect emerges, even though other aspects of the joint task context change.

Additional Analysis

To compare the three experiments, we ran an additional analysis with the magnitude of the Simon effect as dependent variable and experiment (1 vs. 2 vs. 3) as between-subjects factor.

The analysis revealed a significant main effect of experiment, $F(2, 45) = 4.9$, $MSE = 310.41$, $p < .05$. Fischer's LSD post hoc tests confirmed that the magnitude of the Simon effect evident in Experiment 1 differed from the (nonsignificant) effects found in Experiments 2 and 3 ($p_s < .05$), whereas no difference was evident between Experiments 2 and 3 ($p = .39$).

General Discussion

Studies on transfer of learning in individual performance have widely demonstrated that knowledge acquired in a spatial perceptual-motor task can be transferred to and affects the way a subsequent similar task is performed (Proctor & Lu, 1999; see also Iani et al., 2009; Marini, Iani, Nicoletti, & Rubichi, 2011; Ottoboni, Iani, Tessari, & Rubichi, 2013). Two recent studies (Milanese et al., 2010, 2011) showed that this is also true in joint action situations. This may suggest that the two phenomena share the same basic mechanisms. However, in spatial tasks performed in joint contexts, in addition to the spatial relations between stimulus and response, also participants' position is a source of spatial information.

Given the above considerations, the present study was aimed at assessing the relative contribution of S-R and S-P relations in the occurrence of transfer of learning effects. To this aim we modified the social transfer of learning paradigm so that participants could practice either with an incompatible association between stimulus and response positions (Experiment 1) or with an incompatible association between stimulus and participant positions (Experiments 2 and 3). Furthermore, to assess whether changing the position of the response from the practice task to the transfer task played a role, in Experiments 1 and 2 an additional condition was performed in which, in the transfer session, participants were required to switch position and to use the alternative hand to press the same response key used in the practice session.

We found no evidence of SToL when during the practice task the S-R associations were spatially incompatible and the S-P associations were spatially compatible (Experiment 1). This result was evident even when participants changed sitting position during the transfer task and operated the same response key across practice and transfer tasks. On the contrary, a SToL effect, that is, an elimination of the social Simon effect, was found when, during the practice task, the S-P associations were spatially incompatible and the S-R associations were spatially compatible (Experiment 2). The SToL effect was, however, evident only when participants kept the same sitting position from the practice to the transfer task (nonswitch condition). Crucially, Experiment 3 provided converging evidence of the importance of the association between stimulus position and participant position. Indeed, the results of this experiment indicate that the STOL effect emerges as long as participants practice an incompatible association between stimulus position and participant position, even though other aspects of the task context, such as hand placement across the two tasks, change.

[1] We thank Robert Proctor for suggesting Experiment 3.

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The present findings have important theoretical implications because they suggest that, in social contexts, the incompatible association between stimulus and participant positions is crucial for the emergence of transfer effects. It would seem, thus, that in a joint setting, where participants are (implicitly) required to take into account the presence of another person, the relation between participants and stimuli becomes more relevant than the one between the stimulus and the response, that has been shown to be crucial in individual contexts. It may be suggested that in the joint spatial compatibility task participants do not learn which key to press in response to the left or right stimulus, as in the individual two-choice task. Rather, they learn whether they or the other agent should respond.

These results add to an ongoing debate on the mechanisms underlying the social Simon effect and the SToL effect. A key question in this debate is whether correspondence effects emerging in joint settings depend on the relationship between stimuli and responding agents or rather between stimuli and responding effector. Support for the idea that the location of the responding effector may play a role in the occurrence of the joint Simon effect derives from the results by Welsh (2009). To manipulate the position of the responding effector while keeping the participant position constant, Welsh required pairs of participants to perform a joint Simon task with their arms uncrossed or crossed. Whereas in the uncrossed-hand condition, each participant operated the key in front of him/her, in the crossed-hand condition each participant operated the key in the other person's space. The observation of a joint Simon effect in both conditions (see Liepelt, Wenke, & Fischer, 2013 for different results) was interpreted as an indication that the joint Simon effect, similarly to the individual one, depends on the location of the responding effector, hence supporting a task/action corepresentation account.

In contrast, Philipp and Prinz (2010) proposed that the social Simon effect might rely not only on the S-R spatial correspondence (as is known to be crucial for the standard Simon effect to emerge), but also on "social" correspondence, that is, the correspondence between stimulus and responding agents. According to these authors, when the Simon task is shared between two acting individuals, spatial information may be used as an indication of whose turn it is. This would mean that a stimulus appearing on the left does not lead to the automatic activation of the left response, as in the individual version of the task, but rather is perceived as a stimulus signaling that the person sitting on the left is in charge of responding and hence primes the actor on the left or his or her (left) response. This idea has been further elaborated by Wenke et al. (2011) who proposed that correspondence effects observed in social contexts are not the result of the corepresentation of the coagent's task (e.g., the specific S-R mapping used by the coagent) but rather are due to the representation of when it is the other person's turn (agent corepresentation). A support to this idea is provided by the results by Liepelt, Wenke, Fischer, and Prinz (2011) who, analyzing trial-to-trial sequential effects in the social Simon task, found a positive Simon effect when the previous trial was corresponding and a negative Simon effect when the previous trial was noncorresponding. Crucially, although this pattern was comparable between the joint and individual go-nogo conditions, in the joint go-nogo condition, the social Simon effect was more positive after corresponding trials than negative after incompatible trials, while in the individual go-nogo condition the effects were symmetrical. Based on these results, the authors concluded that the irrelevant stimulus location primed the actor or his or her response especially after corresponding trials in which stimulus location corresponded with the actor location, and, as a consequence, response location as a consequence, response location. Hence, this study suggests a crucial role played by the correspondence between stimulus location and actor location.

As stated in the *Introduction*, in the majority of the studies investigating the social Simon effect, the positions of the participant and of the response always corresponded and hence the correspondence between stimulus and response positions could not be dissociated from the correspondence between stimulus and responding agent positions. In Experiments 1 and 2 of the current study, and similarly to Welsh (2009), we separated the positions of the response and of the participant, as in the practice task participants were required to respond with crossed arms. In this way we were able to investigate independently whether the incompatible association between stimulus and response positions (Experiment 1) or the incompatible association between stimulus and participant positions (Experiment 2) is crucial for the SToL effect to occur. Our results seem to support the agent corepresentation account because they clearly show that in social contexts, critical to obtain ToL effects is the spatial relation between stimulus and participant positions while the spatial relation between stimulus and response positions is irrelevant.

It is important to consider that whether the effects evident in social contexts are social in nature is still debated. There are indeed recent findings suggesting that the joint Simon effect might be due to spatial factors (e.g., Dittrich et al., 2013; Dolk et al., 2013) For instance, Dolk et al. (2013) recently suggested that the joint Simon effect might arise because participants code their own actions with respect to salient action events to discriminate between them. Even though it is beyond the aim of the present study to disentangle between social and nonsocial accounts, our results may provide some insights on this issue since they underline the importance of both spatial and social features of the joint task contexts and suggest that acting in a social context increases the importance of the participants' position with respect to the position of the stimuli. Future studies will be aimed at assessing whether the same effects are obtained only in the presence of an intentional coacting agent.

To conclude, in the present study we used the social transfer of learning paradigm to identify which spatial relations are crucial for the emergence of social ToL effects. The results of this study are particularly relevant since they provide insights on what is represented during performance in joint context (see Knoblich & Jordan, 2003).

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