
# The joint flanker effect and the joint Simon effect: On the comparability of processes underlying joint compatibility effects


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# The joint flanker effect and the joint Simon effect: On the comparability of processes underlying joint compatibility effects

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## Abstract

Previous studies observed compatibility effects in different interference paradigms such as the Simon and flanker task even when the task was distributed across two co-actors. In both Simon and flanker tasks, performance is improved in compatible trials relative to incompatible trials if one actor works on the task alone as well as if two co-actors share the task. These findings have been taken to indicate that actors automatically co-represent their co-actor's task. However, recent research on the joint Simon and joint flanker effect suggests alternative non-social interpretations. To which degree both joint effects are driven by the same underlying processes is the question of the present study, and it was scrutinized by manipulating the visibility of the co-actor. While the joint Simon effect was not affected by the visibility of the co-actor, the joint flanker effect was reduced when participants did not see their co-actors but knew where the co-actors were seated. These findings provide further evidence for a spatial interpretation of the joint Simon effect. In contrast to recent claims, however, we propose a new explanation of the joint flanker effect that attributes the effect to an impairment in the focusing of spatial attention contingent on the visibility of the co-actor.

Keywords: Joint compatibility effect, flanker effect, spatial compatibility effect, social Simon effect

Most cognitive research investigating human perception, action, and goal achievement has focused on the study of single individuals performing a cognitive task alone. Yet, in everyday life humans often perform tasks jointly or in the company of others, for example when partaking in team sports or during cooking. In order to succeed in these joint actions, the co-actors have to coordinate their actions with each other (Sebanz, Bekkering, & Knoblich, 2006). Recent research has started to examine joint action by using well-established cognitive tasks (e.g., Atmaca, Sebanz, & Knoblich, 2011; Atmaca, Sebanz, Prinz, & Knoblich, 2008; Böckler, Knoblich, & Sebanz, 2012; Sebanz, Knoblich, & Prinz, 2003; Welsh et al., 2005). The two most prominent of these cognitive tasks are the spatial Simon task (Simon, 1969; for an overview see Lu & Proctor 1995) and the non-spatial flanker task (Eriksen & Eriksen, 1974).

## The Classical Simon and Flanker Task

In the classical Simon task (Simon, 1969), participants respond to a non-spatial stimulus attribute (e.g., discriminate between red or green stimuli) by pressing a left or right response key (e.g., participants press the left key for red stimuli and the right key for green stimuli). Each stimulus is presented randomly either on the left or right side of a computer screen. Although the spatial position is entirely task-irrelevant, participants typically respond faster and make fewer errors when the spatial position of the stimulus and the required response key match (compatible trials) compared to when they do not match (incompatible trials). This effect is known as the spatial compatibility effect (SCE) or Simon effect. It is widely accepted that the SCE occurs due to a conflict at the response selection stage (De Jong, Liang, & Lauber, 1994; Rubichi & Pellicano, 2004; Treccani, Cubelli, Della Sala, & Umiltà, 2009). According to the dimensional overlap model (Kornblum, Hasbroucq, & Osman, 1990) this conflict is caused by an overlap between the stimulus dimension and the response dimension. Specifically, it is assumed that the spatial feature of the stimulus directly activates the spatially corresponding response (e.g., a red stimulus displayed on the left directly activates the left key). The automatic activation of the spatially corresponding response leads to facilitation effects when this response is correct and to interference effects when it is incorrect. For example, if the color red is mapped onto the left response key, a red stimulus displayed on the left directly activates the correct left key. However, if the same stimulus is displayed on the right, it directly activates the incorrect right key and requires time-consuming correction processes (for other accounts of the Simon effect see Ansorge & Wühr, 2004; De Jong et al., 1994; Eimer, Hommel, & Prinz, 1995).

The classical, so-called Eriksen flanker task (Eriksen & Eriksen, 1974) is a cognitive task that does not include a spatial stimulus-response relation. In the classical flanker experiment, participants have to respond to the central letter (e.g., H) of a five-letter string (e.g., KKHKK) by pressing one of two response keys (e.g., left key for H and K; right key for S and C). The surrounding letters are called flankers and can either be compatible (e.g., KKHKK or HHHHH), incompatible (e.g., SSHSS or CCHCC), or neutral (e.g., UUHUU) with respect to the imperative target (e.g., H). Though the flankers are task irrelevant, performance is impaired when the flankers are incompatible relative to conditions in which they are compatible or neutral. This difference is typically called flanker effect. Whereas the Simon effect is attributed to a stimulus-response overlap, the flanker effect belongs to a different type of interference effect that stems from a stimulus-stimulus overlap (i.e., target-flanker overlap; e.g., Kornblum & Lee, 1995). Kornblum et al. (1990) assumed that interference from a stimulus-stimulus overlap occurs at a perceptual level producing perceptual facilitation in case of compatible trials and perceptual interference in case of incompatible trials. However, there is converging evidence that interference from stimulus-stimulus overlap mostly arises at the response selection stage. Specifically, it has been postulated that flanker stimuli facilitate response selection in case of compatible trials and impair response selection in case of incompatible trials (e.g., Cohen & Shoup, 1997; De Houwer, 2003; Eriksen & Eriksen, 1974; Treccani et al., 2009). In contrast to stable and ingrained associations between a stimulus and a response driving spatial compatibility effects (e.g., a stimulus presented on the left automatically activates a left button press), episodic and transient associations between a stimulus and a response created by instructions are assumed to explain the flanker effect (e.g., participants learn that the letter H requires a left button press; for a discussion of this issue see De Houwer, 2003; Treccani et al., 2009).

**The Joint Simon and Joint Flanker Effect**

The Simon and the flanker task have both been skillfully redesigned to scrutinize joint action and joint task representation. In their seminal work, Sebanz et al. (2003) distributed the *Simon task* across two subjects to explore whether co-actors represent each other's actions. In such a joint go/no-go setting or social Simon task, participants sat alongside each other in front of a computer monitor; each participant responded to only one of the two stimuli by pressing one of the two response keys (e.g., one participant pressed the left key for red stimuli and the other participant pressed the right key for green stimuli). This joint-action condition elicited a Simon effect such that performance was improved when the stimulus position matched the position of the responding agent. The occurrence of the so-called joint SCE or social Simon effect is particularly interesting given that the SCE typically disappears in an individual go/no-go task where participants respond to only one of the two stimuli by pressing just a single response key but without a co-actor seated next to them (Hommel, 1996; Sebanz et al., 2003). Sebanz et al. (2003) interpreted the pattern of joint SCE in terms of action co-representation: According to their explanation, subjects represented the actions of their co-actor in addition to their own actions. This assumption is based on the theory that the executed actions of oneself and the perceived actions of another person are coded in an equivalent way (e.g., Prinz, 1990, 1997). Sebanz et al. (2003) assumed that this equivalent coding results in a cognitive representation of both the actions of the co-actor and the spatial alignment of the two responses. Therefore, performing a Simon task together with a co-actor should lead to a similar stimulus-response-overlap as in the classical Simon task (Sebanz et al., 2003).

Following the same line of reasoning, Atmaca et al. (2011) distributed the *flanker task* across two subjects. In a joint go/no-go setting, participants sat alongside each other. Each participant responded to two targets by pressing one response key. For example, one participant pressed the left key for the targets H or K and the other participant pressed the right key for the targets S or C. In the individual go/no-go version of the flanker task, participants still responded to two targets (e.g., H and K) but without a co-actor next to them. Atmaca et al. (2011) found the flanker effect to be larger in the joint task setting than in the individual task setting and they interpreted this increased flanker effect as evidence for action co-representation: According to this view, subjects represented the actions of their co-actor in addition to their own actions. If the target (e.g., H) is surrounded by flankers (SSHSS) that are part of the co-actor's response (e.g., S), participants will activate the representation of their co-actor's action alternative. This activation in turn interferes with one's own required response (Atmaca et al., 2011).

Taken together, the Simon and the flanker paradigm initially seemed to be promising candidates for scrutinizing joint actions, and numerous studies have supported Sebanz et al.'s (2003) account of action co-representation, for example by demonstrating that different social factors modulate the joint Simon effect (e.g., Hommel, Colzato, & van den Wildenberg, 2009; Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011; Müller et al., 2011; Stenzel et al., 2012). However, the idea of action co-representation as an explanation of joint compatibility effects has recently been challenged. For the Simon task, recent findings showed that the joint SCE might be based on the spatial components immanent in the task itself (e.g., Dittrich, Dolk, Rothe-Wulf, Klauer, & Prinz, 2013; Dittrich, Rothe, & Klauer, 2012; Dolk et al., 2011; Dolk, Hommel, Prinz, & Liepelt, 2013; Guagnano, Rusconi, & Umiltà, 2010). For example, Dittrich et al. (2012) have shown that Simon effects occur in an individual go/no-go condition when the spatial dimension is made more salient by using an appropriate response device, such as a joystick (for another experimental manipulation that made the spatial dimension in a spatial individual go/no-go task salient see Weeks, Proctor, & Beyak, 1995). Further, Dittrich et al. (2013) observed joint Simon effects only if the spatial alignment of participants *and* response keys corresponded to the spatial dimension of the Simon task but not if just one dimension mismatched (i.e., was orthogonal to the others). Dittrich et al. (2012, 2013) developed the *spatial response coding account* that emphasizes the importance of spatial labels or codes aligned with the spatial dimension of the Simon task for (joint) SCEs to occur (for a similar account explaining SCEs in the classical Simon task, see Ansorge & Wühr, 2004).

Dolk et al. (2011, 2013) developed another rather global account to explain social Simon effects. They argued that participants represent their own actions as well as any other event during the task. The presence of any attention-grabbing event (e.g., a co-actor responding to a stimulus) requires participants to discriminate between events controlled by themselves and events that they do not control. One way of solving this discrimination problem is to strengthen distinguishable features of response events such as the left-right location of the response device. However, this increased intentional weighting (Memelink & Hommel, 2013) automatically increases interference (e.g., the more the left/right coding of one's own response is strengthened the more it interferes with the task-irrelevant stimulus location). Dolk et al. (2013) demonstrated that even non-social events elicit an SCE: A Simon effect emerged when participants performed the individual go/no-go task next to an inanimate object (Japanese waving cat, a clock, or a metronome). They argued that these inanimate objects also represent an attention-grabbing event (similar as a co-actor responding to a stimulus) that requires participants to discriminate between self-controlled events and events that they do not control. Importantly, Dolk, Hommel, Prinz, and Liepelt (2014) assumed that the same mechanisms are responsible for the joint flanker effect. The co-actor in the joint flanker task is also assumed to induce a discrimination problem requiring participants to distinguish between events that they control and events controlled by the co-actor. This discrimination problem should lead to an increased intentional weighting of specific discriminable stimulus features. The more the activated response alternatives in turn differ, the stronger should be the conflict between targets and the flankers. To test this assumption, Dolk et al. (2014) had participants perform the joint flanker task either together with a human or next to a Japanese waving cat. The results showed significant flanker effects in both conditions.

**On the Comparability of Processes Underlying Joint Simon and Joint Flanker Effects**

Although Dolk et al. (2014) provide an intriguing non-social account for joint compatibility effects in general, it is desirable to characterize the underlying cognitive processes in more detail. As explained above, Dittrich et al. (2012, 2013) developed a more task-specific *spatial response coding account* to account for social Simon effects that emphasizes the importance of spatial labels or codes aligned with the spatial dimension of the Simon task. If such task-specific processes modulate (joint) Simon effects, the assumption that comparable processes underlie joint Simon and joint flanker effects has to be carefully scrutinized. The present work sets out to test empirically whether joint Simon and joint flanker effects share comparable processes. In fact, a positive result could be argued to be quite surprising given that the processes underlying the standard Simon and flanker effect are assumed to differ. Considering the joint interference tasks, it seems less reasonable to assume that spatial response coding explains joint flanker effects. Even if a joint setting enhances spatial response coding when participants perform a flanker task, this might not enhance flanker effects: A (non-)correspondence between flankers and response position should not be the key factor underlying (joint) flanker effects. If not via spatial response-coding (and also not via shared task-representations; see Dolk et al., 2014) what else might explain joint flanker effects? A quite simple explanation would be that a co-actor or a Japanese waving cat attracts participants' attention leaving less cognitive resources available to focus spatial attention on the location of the target and leading to interference from the flanker stimuli. To examine the influence of attentional processes in the joint Simon and joint flanker effect, we manipulated the role of the co-actor at the perceptual level by modulating his or her visibility. As will be elaborated below, the influence of the visibility of the co-actor has already been investigated, specifically for the Simon task, but the exact implementation of the manipulation seems to affect the result pattern strongly (with some studies showing joint interference effects when the co-actor is not visible or present and others that do not). We will therefore use exactly the same manipulation in both joint interference tasks to examine the influence of attentional processes in the joint Simon and joint flanker effect.

For the joint Simon task, no influence of the visibility of the co-actor is expected. Previous studies have already shown that a joint SCE prevailed when participants believed to perform the joint go/no-go task together with a co-actor in a different room (Ruys & Aarts, 2010; Tsai, Kuo, Hung, & Tzeng, 2008) or when the participants wore opaque goggles (Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010). However, joint effects only prevailed when participants had a vivid idea of where the co-actor was seated and when task instructions allowed a spatial response coding (but see Sellaro, Treccani, Rubichi, & Cubelli, 2013; Welsh, Higgins, Ray, & Weeks, 2007, for different results) in line with the spatial response coding account (Dittrich et al., 2012, 2013). For the flanker task, we do expect an influence of the visibility of the co-actor on the size of the joint effect if the effect involves attentional processes. We presume that a visible co-actor attracts at least some attention making it more difficult for participants to focus their spatial attention on the location of the target. In turn, flanker interference is assumed to be increased and target discrimination is assumed to be impaired compared to a condition with an invisible co-actor. In contrast, if both the joint Simon task and the joint flanker task share the same underlying processes (e.g., Atmaca et al., 2011; Dolk et al., 2014), the visibility manipulation should lead to similar results for the joint Simon and the joint flanker task. In fact, in line with previous research (e.g., Ruys & Aarts, 2010; Tsai et al., 2008), joint effects should be independent of the visibility of the co-actor.

To sum up, the present study investigates the comparability of the joint Simon and joint flanker effect. We hypothesize that underlying processes differ and we test the hypothesis via the manipulation of the visibility of a co-actor. In the experiment, pairs of participants performed both tasks either with a partition panel between them or without a partition panel between them. In order to prevent acoustical feedback from key presses, participants wore headphones. In the present work, we define a joint Simon effect as well as a joint flanker effect as the difference between incompatible and compatible trials in a joint Simon and joint flanker task condition, respectively, analogous to several studies reported so far (e.g., Dittrich et al., 2013; Guagnano et al., 2010; Hommel et al., 2009; Iani et al., 2011; Welsh, 2009). In order to rule out the possibility that the partition panel per se influences the performance in one or both interference tasks, we also implemented an individual go/no-go condition that was to be performed prior to the joint go/no-go condition with either a partition panel present or absent (see Figure 1). We expected performance in both the individual go/no-go flanker and individual go/no-go Simon task to be independent of the presence of a partition panel. Participants performed either the individual and the joint Simon task or the individual and the joint flanker task.

## Method

### Participants

A group of 80 undergraduate and graduate students (66 female and 14 male; mean age = 22.4 years, *SD* = 5) of the University of Freiburg participated for fulfillment of course credits. All subjects had normal or corrected-to-normal vision. Subjects were randomly assigned to one of four experimental conditions defined by task (Simon task vs. flanker task) and partition group (partition vs. no partition). All participants were tested in same-gender pairs. Three participants were excluded from analysis because they did not understand the task and did not respond to the go stimuli or responded to both the go and the no-go stimuli.

**Materials and Apparatus**

For the Simon task we adjusted the stimuli used by Tsai, Kuo, Jing, Hung, and Tzeng (2006): Three unfilled white circles (aligned horizontally; with a 1 cm radius and 0.5 cm circle-distance) were surrounded by a white rectangle (9 cm length x 3.4 cm width) and presented on a black background in the center of a computer screen. The target stimuli were either a green filled circle or a red filled circle and replaced one of the three white circles one at a time. Participants were requested to respond to either red or green stimuli. Target stimuli presented in the middle position were defined as neutral trials.

The stimuli for the flanker task were adapted from Atmaca et al. (2011; Experiment 2): As in the Simon task, three unfilled white circles were surrounded by a white rectangle and presented on a black background in the center of a computer screen. Targets were either red, green, yellow, or blue filled circles that replaced the middle circle. In each trial, flankers in red, green, yellow, blue, or white (for neutral trials) replaced the circles to the right and left of the target; both flankers had the same color in each trial. Participants were requested to respond to two target colors (e.g., red and green). Flankers were either colored circles mapped onto one’s own response key (in this example red or green) or colored circles mapped onto the partners response key (in this example yellow or blue), or flankers were white circles (neutral trials).

The participants of both tasks (Simon task and flanker task) responded with the interior key of a computer mouse (Voss, Leonhart, & Stahl, 2007; see Figure 1). All participants pressed the interior key with the index finger of their right hand. The computer mice were placed 70 cm in front of the PC monitor (see Figure 1).

**Procedure**

Participants performed either the Simon task or the flanker task. Upon arrival at the laboratory, pairs of participants were briefed that they would first be tested in individual sessions (go/no-go task as control condition; see Figure 1 left). The two participants performed the two individual conditions in turns: the first randomly selected participant was seated on the left side and was informed that he or she is participant 1 (their chair was marked with a 1); after the first participant finished his or her individual task the second participant was seated on the right side and was informed that he or she is participant 2 (their chair was marked with a 2).[1] While one participant was tested, the other participant was asked to wait in front of the room. The participants received written instructions about their task on the PC monitor (e.g., Simon task: "Please press the marked key of the computer mouse with your right index finger if the green circle appears and do not respond if the red circle appears"; flanker task: "Please press the marked key of the computer mouse with your right index finger if a green or red circle appears in the middle circle and do not respond if a yellow or blue circle appears in the middle circle" [original instructions in German]). The participants were instructed to respond to the go stimuli as fast and accurately as possible. In the individual session, the participants performed two practice blocks each consisting of 30 trials to familiarize themselves with their task and two experimental blocks each consisting of 120 trials (altogether four experimental blocks of the individual go/no-go condition were administered, two per each participant). Colors were distributed equally across all possible stimulus positions (with the constraint in the flanker task that both flankers had the same color in each trial).

After the individual sessions, the participants were tested together in a joint session (see Figure 1 right) and seated according to their position in the individual tasks (participant 1 on the left, participant 2 on the right). Participants received written instructions that they were to respond to the same stimuli as before (e.g., Simon task: "Participant 1: Please press the marked key of the computer mouse with your right index finger if the green circle appears and do not respond if the red circle appears. Participant 2: Please press the marked key of the computer mouse with your right index finger if the red circle appears and do not respond if the green circle appears."; analogous instructions apply to the flanker task). Instructions were displayed on the computer screen and were visible for both participants. In the joint session, participants performed four experimental blocks each consisting of 120 trials. Again, colors were distributed equally across all possible stimulus positions.

**Trial sequence.** In the beginning of each trial, the rectangle with three white circles inside was presented for 400 ms, followed by the target display for 150 ms. The measurement of reaction time started with the onset of the target display and subjects had 600 ms to respond (later responses were counted as omissions).[2] The inter-trial-interval was 500 ms. In the individual sessions, participants received error feedback in the practice block if they responded too slowly ("too slow" [in German] was displayed for 500 ms) or incorrectly ("error" [in German] was displayed for 500 ms). For the Simon task, we counterbalanced whether the right or left participant had to respond to the green or the red target. For the flanker task, we counterbalanced the different target mappings (red and green; red and blue; red and yellow; green and blue; blue and yellow; yellow and green) across participants seated on the right or on the left.

**Partition group.** Pairs of participants were randomly assigned to the partition group or the no-partition group. In the partition group, the procedure, instructions, and treatment of the subjects were identical to the no-partition group, except that participants were separated by a partition panel (193 cm height × 120 cm width). The panel was positioned between participants in such a way that they could neither see the other participant nor his or her response mouse. In the partition group, the panel was already in place for the individual condition (see Figure 1, panel B for the individual partition condition and the joint partition condition). By default, participants wore headphones in all partition and no-partition conditions in order to make key presses inaudible which was particularly relevant for the joint partition condition.

**Design.** The experiment had a 3 (compatibility: compatible, incompatible, neutral) × 2 (condition: individual go/no-go, joint go/no-go) × 2 (partition group: partition panel, no partition panel) × 2 (task: Simon task, flanker task) design; the first two factors were manipulated within-subjects.

**Results**

From each participant's reaction times, we excluded false alarm and omission trials as well as response times that were outliers defined by Tukey's criterion (response times one and a half times the interquartile range or more above the third quartile or below the first quartile, Clark-Carter, 2004, chap. 9). This led to the exclusion of 4.42% of trials in the Simon task and 4.49% of trials in the flanker task. In the error analyses, both false alarm and omission trials were coded as error. Tables 1 and 2 show mean reaction times and mean error rates for compatible, neutral, and incompatible trials separately for task condition (individual go/no-go vs. joint go/no-go) and partition group (partition panel vs. no-partition panel).

The accuracy and latency data were analyzed in a mixed linear model analysis. The advantage of such an analysis is that not only systematic variation between individual participants but also systematic variation between pairs of participants can be taken into account (i.e., it is reasonable to assume that individual participants adapt their responding behavior to their co-actor's behavior, resulting in systematic variation between pairs of participants).[3] Accuracy and latency data were analyzed in two steps, separately for the Simon task and the flanker task. In the first step, we estimated mixed linear models (for the accuracy data: generalized mixed linear models with logistic link function) with *participants* and *pairs of participant* as random factors.[4] In this first step, we identified the random structure that fits the data best. Specifically, analyses revealed whether a random intercept for participants is sufficient, or whether an additional random intercept for pairs of participants and/or random slope components for the experimental within-subject factors (compatibility; joint go/no-go task, individual go/no-go task) as a function of participants or pair of participants are necessary (Judd, Westfall, & Kenny, 2012). The selection of the model with appropriate random structure is described in the Appendix. In the second step, the model with appropriate random-effects structure was used to check the fixed effects of two within-subject factors *compatibility* (compatible vs. neutral vs. incompatible) [5] and *condition* (individual go/no-go vs. joint go/no-go) and the between-subjects factor *partition group* (partition panel vs. no-partition panel). Delta chi-square statistics are used for the accuracy data, and *F* statistics with Kenward-Roger approximated degrees of freedom for the latency data (Judd et al., 2012). The results for the fixed effects are presented below, separately for the Simon and the flanker task.

**Simon Task**

*Accuracy:* The analysis of the fixed effects revealed a marginally significant main effect of compatibility, $\chi^2[df = 2] = 5.16$; $p = .08$, indicating that more errors were made in incompatible trials compared to compatible trials. The difference between incompatible and compatible trials was larger in the individual than in the joint go/no-go condition, $\chi^2[df = 2] = 5.89$; $p = .05$, and this interaction was additionally modulated by partition group, $\chi^2[df = 2] = 6.65$; $p = .04$. Separate follow-up analyses for the joint go/no-go condition and the individual go/no-go condition with the factors compatibility (compatible vs. incompatible vs. neutral) and partition group (partition panel vs. no-partition panel) revealed a small compatibility effect in the individual go/no-go condition, $\chi^2[df = 2] = 6.51$; $p = .04$, while all other effects were not significant (largest $\chi^2 = 4.34$; smallest $p = .11$).

*Reaction time:* The analysis of the fixed effects revealed a main effect of compatibility, $F(2, 33.96) = 27.68$, $p < .001$, indicating faster responses to compatible and neutral trials compared to incompatible trials. There was also a main effect of condition, $F(1, 34.99) = 13.63$, $p < .001$, indicating that responses were faster in the joint go/no-go condition than in the individual go/no-go condition. The analysis further showed a significant interaction effect of compatibility and condition for reaction time, $F(2, 33.93) = 6.80$, $p < .01$. This indicates that individual go/no-go and joint go/no-go conditions differ in their mean reaction times depending on the level of compatibility. Separate follow-up analyses of reaction time of the joint go/no-go and the individual go/no-go condition with the factors compatibility (compatible vs. incompatible vs. neutral) and partition group (partition panel vs. no-partition panel) revealed a main effect of compatibility in the joint condition ($F[2, 33.90] = 39.37$, $p < .001$).[6] Contrary to what is typically found in individual go/no-go task, there was also a main effect of compatibility in this condition ($F[2, 33.97] = 6.64$, $p < .01$). We turn to this unexpected result in the general discussion. Importantly, neither the SCE in the individual go/no-go condition nor in the joint go/no-go condition was affected by partition panel, indicated by a non-significant interaction of compatibility and partition panel ($F$s < 1). In the main analyses, no significant effect of partition group was found, indicating that both the partition group and the no-partition group did not differ in their overall performance, $F < 1$. Importantly, the compatibility × partition group × condition interaction was also not significant $F < 1$, suggesting that the compatibility × condition interaction described above was equivalent in the partition group and no-partition group as expected.

One pattern in the data might be counterintuitive from theoretical perspectives on SCEs (e.g., De Jong et al., 1994; Kornblum & Lee, 1995): As depicted in Table 1 mean reaction times in the Simon task were shorter for neutral trials than for compatible trials which might imply that the effect pattern reported above was primarily driven by neutral trials. However, when excluding neutral trials from the analyses reported above, the same effect pattern emerged: We still found a main effect of compatibility in the joint go/no-go condition, $F(1, 5510.03) = 7.22$, $p < .01$, and in the individual go/no-go condition, $F(1, 2840.04) = 4.87$, $p = .03$. In both, the analysis of the joint go/no-go task and the analysis of the individual go/no-go task, there was neither a main effect of partition panel nor an interaction of partition panel and congruency ($F$s < 1). Additionally, descriptive accelerations of reaction times for neutral trials in individual and/or joint go/no-go conditions have been reported by several research groups before (e.g., Dittrich et al., 2012; Sebanz et al., 2003, Experiment 2; Tsai et al., 2008; Welsh et al., 2007; for a possible explanation of this effect see Umiltà, Rubichi, & Nicoletti, 1999).

**Flanker Task**

*Accuracy:* The analysis of the fixed effects revealed a main effect of compatibility, $\chi^2[df = 2] = 169.84$; $p < .01$, indicating that more errors were made in incompatible trials relative to neutral and compatible trials. Moreover, more errors were made in the individual go/no-go condition, $\chi^2[df = 1] = 8.85$; $p < .01$. Additionally, in the individual go/no-go condition, there tended to be a difference in the flanker effect between partition groups while flanker effects were identical in the partition groups of the joint go/no-go condition as indicated by a marginally significant interaction of compatibility, condition, and partition group, $\chi^2[df = 2] = 5.08$; $p = .08$ (see also Table 2). However, in a follow-up analysis of the individual go/no-go condition with the factors compatibility (compatible vs. incompatible vs. neutral) and partition group (partition panel vs. no-partition panel), the flanker effects in the partition and the no partition group did not differ significantly (the interaction between partition group and compatibility did not reach significance, $\chi^2[df = 2] = 1.43$; $p = .49$).

*Reaction time:* The analysis of the fixed effects revealed a main effect of compatibility, $F(2, 13667.29) = 76.47$, $p < .001$, indicating that responses to compatible and neutral trials were faster than responses to incompatible trials. There was also a main effect of condition, $F(1, 38.50) = 25.97$, $p < .001$, indicating that responses were faster in the joint go/no-go condition than in the individual go/no-go condition. The analyses revealed no main effect of partition group, indicating that both the partition group and the no-partition group did not differ in their overall reaction time, $F < 1$. Importantly, the analysis revealed a significant compatibility × condition × partition group interaction, $F(2, 13667.32) = 4.47$, $p = .01$. Note that the two-way interaction between compatibility and partition group was not significant ($F < 1$), indicating that the flanker effect was not per se larger in the no-partition panel group.

To interpret this three-way interaction, follow-up analyses were conducted separately for the joint go/no-go condition and the individual go/no-go condition with the factors compatibility (compatible vs. incompatible vs. neutral) and partition group (partition panel vs.

no-partition panel). The compatibility × partition group-interaction was significant in the joint go/no-go condition, $F(2, 9121.03) = 2.96$, $p = .05$, revealing larger flanker effects in the no-partition panel group compared to the partition panel group; this interaction was not significant in the individual go/no-go condition, $F(2, 4546.05) = 1.90$, $p = .15$.

The same effect pattern emerged in analyses excluding neutral trials. We still found a significant compatibility × condition × partition group-interaction, $F(1, 10893.48) = 4.94$, $p = .03$, and the compatibility × partition group-interaction was only significant in the joint go/no-go condition, $F(1, 7273.03) = 4.51$, $p = .03$, but not in the individual go/no-go condition, $F(1, 3620.06) = 1.43$, $p = .23$.

**Joint Analysis of Simon and Flanker Task**

Due to the identical factorial design, it is possible to conduct an analysis including both the flanker and the Simon task. This joint analysis (for the random effect structure of the model see Appendix) revealed a marginally significant compatibility × condition × partition group × task interaction for reaction time, $F(2, 73.66) = 2.52$, $p = .09$, tentatively confirming the moderation of compatibility effects in individual and joint go/no-go conditions by partition group in the flanker task, and the absence of an equivalent effect pattern in the Simon task. The same analysis excluding neutral trials revealed a similar result, $F(2, 75.49) = 3.26$, $p = .07$.

## Discussion

The present study aimed to explore whether the joint Simon task and the joint flanker task share the same underlying processes. This issue was addressed by investigating whether the visibility of the co-actor moderates joint Simon and joint flanker effects to the same degree. In the Simon task, joint SCEs did not differ between the partition group and no-partition group. As expected, SCEs were also observed when the two participants were separated by a partition panel. In contrast, in the joint flanker task, joint interference effects differed between the partition group and no-partition group, revealing larger effects when the participants were not separated by a partition panel and thus, were able to see each other.

The fact that both tasks differed in their results for the partition groups suggests that the joint flanker and the joint Simon task do not draw upon the same cognitive processes. For this reason, we propose different mechanisms for both joint effects, in line with well-established accounts of both standard tasks. The joint Simon effect can be explained by the spatial coding account (Dittrich et al., 2012, 2013): The joint SCE emerged in both partition groups because participants knew *where* their respective co-actor was seated in relation to themselves, no matter if they could see the co-actor or not. This knowledge enabled participants to refer to themselves as the right or left participant and to code their responses spatially. In turn, the spatial response coding led to a stimulus-response-overlap that caused shorter response times in compatible trials than in incompatible trials.

To explain the joint flanker effect, we propose a new explanatory approach: We assume that joint flanker effects are caused by less focused spatial attention in the joint flanker task due to the presence and visibility of another person. In turn, the task-irrelevant flankers receive more attention, and thus more activation amplifying the conflict between targets and flankers. This reasoning is in line with several empirical findings that demonstrate the modulation of flanker effects by the size of the focus of spatial attention (e.g., LaBerge, 1983; Mattler, 2006; for an overview see Hübner, Steinhauser, & Lehle, 2010). The attentional-focus account is also in line with the results observed by Dolk et al. (2014): The fact that the flanker effect increased when a Japanese waving cat was placed next to the participants might be due to the additional attention required by the waving cat, consuming cognitive resources that are needed to focus spatial attention to the target position.

Both the attentional-focusing account postulated here and Dolk et al.’s (2014) reasoning state that “attention-grabbing events” like co-actors or Japanese waving cats induce joint flanker effects. However, both accounts diverge in their assumptions about the fundamental processes. In their referential coding account, Dolk et al. (2014) assumed that the joint flanker task and the joint Simon task rely on the same fundamental mechanism. In both joint interference tasks, the co-actor (or a Japanese waving cat) should induce a discrimination problem that requires the participants to distinguish between events that they control and events controlled by the co-actor. This discrimination problem should lead to an increased intentional weighting of specific discriminable stimulus features. The more the activated response alternatives in turn differ, the stronger should be the interference effect. According Dolk et al.'s (2014) reasoning, all joint conditions of the present experiment should have led to the need to distinguish between self-controlled and not self-controlled events because the two complementary stimulus-response rules in the instructions were explicitly mentioned. Therefore, joint Simon or joint flanker effects should be affected in the same way by whether the co-actor is visible or not. However, in our study only the flanker but not the Simon effect was affected by the visibility of the co-actor. We assume that "attention-grabbing events" like co-actors or Japanese waving cats impair participants in focusing their spatial attention to the target, and we will discuss possible reasons for that below.

According to a shared task-representation account of the joint flanker task (Atmaca et al., 2011), a joint flanker effect should occur if participants cannot see each other but know of the co-actor's actions. Thus, according to Atmaca et al. (2011), joint flanker effects should not be affected by the partition arrangement. Since joint flanker effects were affected by the partition arrangement, the present data do not confirm the shared task-representation account. Note also that even Atmaca et al. did not find an overall joint flanker effect (they defined joint flanker effects as the difference of flanker effects between a joint and an individual go/no-go condition) in their third experiment when participants were told that a co-actor would perform the complementary task in another room.

It should be noted that the present experiment was designed to examine whether similar processes underlie joint flanker and joint Simon effects as proposed previously

(Atmaca et al., 2011; Dolk et al., 2014), but it was not designed to rule out the referential coding account by Dolk et al. (2014) or the shared task-representation account by Sebanz et al. (2003; see also Atmaca et al., 2011). Nevertheless, both accounts have difficulties to explain why the Simon effect was independent of the visibility of the co-actor while the flanker effect was affected by the partition arrangement. Further, although we pursue non-social interpretations of joint Simon and joint flanker effects based on results reported previously (e.g., Dolk et al., 2013, 2014; Dittrich et al., 2012, 2013), much research demonstrates that different social factors modulate the joint Simon effect (e.g., Hommel et al., 2009; Iani et al., 2011; Müller et al., 2011; Stenzel et al., 2012). Thus, it seems likely that social factors, if not being causal, at least moderate joint interference effect. Finally, it is important to note that although the present findings challenge the action co-representation account for the joint flanker and the joint Simon effect, our study does not intend to disconfirm the phenomenon of action co-representation in general. Future research on joint action should develop and use cognitive tasks that are capable to measure action co-representation, but that are not influenced by the attentional focus of the participants or the spatial dimension within the experimental set-up (for example the inhibition of return effect, see Welsh et al., 2005, but see Atkinson, Simpson, Skarratt, & Cole, 2014; Cole, Skarratt, & Billing, 2012).

**Open Questions and Future Directions**

In the present work, we assume that the presence of a co-actor impairs participants' abilities to focus their spatial attention on the target stimuli impeding in particular performance in the flanker task. Presumably, a co-actor (or of a Japanese waving cat; see Dolk et al., 2014) attracts participants' attention because the co-actor appears in the participants' visual area. Participants might be less able to concentrate on the target compared to an individual go/no-go condition because cognitive resources are required for monitoring the co-actor (or Japanese waving cat). Note that this assumption is similar to assumptions formulated in the social presence literature. Guerin (1983) for example speculated that cognitive distraction might in part explain why the presence of another person affects task performance. The modulation of the joint flanker effect due to impaired cognitive resources is in line with research demonstrating that high working memory load or task coordination lead to increased distractor interference in the classical flanker task (Lavie, Hirst, de Fockert, & Vidig, 2004). Another explanation might be that the co-actor in the joint flanker task induces arousal which impairs cognitive control processes. This interpretation is supported by recent research of Dreisbach and Böttcher (2011) who showed that performance in a flanker task was impaired in a social-evaluative context. Specifically, female participants showed impaired performance in incompatible flanker trials when another person was present evaluating pictures of women. Performance was not impaired when the other person was evaluating pictures of landscapes or when the person was merely present without performing a task. Dreisbach and Böttcher (2011) argued that the specific social-evaluative context might have induced a negative affect impairing cognitive control processes. However, while it might seem plausible that a co-actor induces arousal or even a mild negative affective reaction because of the fear to be evaluated, it seems less reasonable that similar reactions are induced by the Japanese waving cat.

In the present work, we focused on the joint condition of the Simon and flanker task and we defined joint interference effects by the difference between incompatible and compatible trials, analogous to several studies reported so far (e.g., Dittrich et al., 2013; Guagnano et al., 2010; Hommel et al., 2009; Iani et al., 2011; Welsh, 2009). In order to rule out that the partition panel per se influenced the performance in one or both interference tasks, individual go/no-go tasks were also implemented. As expected, performance in both individual go/no-go flanker and individual go/no-go Simon task was independent of the presence of a partition panel indicating that the effect of the partition panel was specific to task and setting. Nevertheless, the results of both individual go/no-go tasks raise a few unanswered questions because in both tasks a compatibility effect emerged. For the flanker task, Dolk et al. (2014) and Atmaca et al. (2011) assumed different reasons for the occurrence of a flanker effect in an individual go/no-go setting. According to Atmaca et al. (2011), the flanker effect in an individual condition appears due to a conflict between relevant and irrelevant stimulus features. This hypothesis rests on the fact that incompatible flankers in contrast to neutral flankers sometimes appear in the target position and thus might activate a stronger inhibition than neutral flankers. In contrast, Dolk et al. (2014) suggest that in the individual flanker task the irrelevant flankers activate an alternative stimulus-response rule even if this stimulus-response rule is neither explicitly formulated nor in use in the individual go/no-go flanker task. On the basis of the present findings, both reasons for the occurrence of a flanker effect in the individual go/no-go task are possible. Future research will have to investigate in more detail (a) the origin of the individual go/no-go flanker effect and (b) reasons for the fact that the effect is smaller in the individual condition than in the joint condition or in the classical flanker task. For the Simon task, the unexpected result emerged that a significant SCE was even found for the individual go/no-go condition, contrary to previous findings (e.g., Sebanz et al., 2003). We assume that participants might have coded their responses as left or right, even without a co-actor present. Participants were explicitly recruited in pairs, they arrived at the lab together, they were instructed to wait for their co-actor in front of the room, and they were seated on marked chairs (left chair was marked with a 1 for participant 1, right chair was marked with a 2 for participant 2). Probably, this procedure made it easy for the subjects to anticipate that their co-actor will perform or did perform a similar task sitting on the other available seat. Therefore, even the individual go/no-go condition made it possible for the participants to code their responses spatially.

One limitation of the present study is that the order of the individual and the joint conditions was not counterbalanced. We did this in an attempt to prevent carryover effects of spatial response coding from the joint Simon task to the individual Simon task. It was assumed that if subjects performed the joint Simon task prior to the individual Simon task, they would have thought of themselves as the right or left participant; this spatial response coding could have been carried over to the individual Simon task. To standardize measurements, we also did not counterbalance the order of the individual and the joint condition in the flanker task. This strategy might cause the concern that practice effects have led to an attenuation of the compatibility effects of the joint Simon and joint flanker task. However, previous studies have shown that spatial compatibility effects of the Simon task are quite resistant against practice effects (Dutta & Proctor, 1992) and compatibility effects of the flanker task are reasonably robust (Brown & Fera, 1994). Moreover, even if practice effects have been present, they should have affected both joint conditions – Simon and flanker - equally. The results showed higher or equal compatibility effects compared to the individual tasks for all joint go/no-go conditions. Given that practice effects should have led to decreased compatibility effects in all joint conditions, the differences in the joint flanker task between the partition and no-partition condition in particular cannot reflect possible practice effects.

A new aspect of the present work is the use of mixed linear models instead of analyzing data with repeated-measures ANOVAs. One advantage of this kind of analysis for experiments in the research field of joint action is the possibility to account for random effects produced by pairs of participants (note that Baus et al., 2014 also used mixed linear models to analyze joint task performance, but in their work only *participants* and *items* but not *pairs of participants* were included as random factors). It is reasonable to assume that participants adapt their responding behavior to their co-actor's behavior, but classical analyses do not incorporate this "pair factor". By including the "pair factor" as random factor in the mixed linear model analyses, we found an influence of this factor in all analyses (see Appendix). Future work in the research field of joint action might profit from using mixed linear models not only to assess this "pair factor" but also to reduce substantial biases in analyses that ignore relevant random effects (Judd et al., 2012).

To conclude, the present study suggests that two different processes underlie the joint Simon task and the joint flanker task by showing that different effects emerged for both tasks as a function of whether the co-actor is visible or not. Results of the Simon task are in line with a spatial interpretation of the joint Simon effect: In both partition groups, participants knew where their respective co-actor was seated in relation to themselves, inducing a spatial response coding. In contrast to recent claims, we propose a new explanation of the joint flanker effect that attributes the joint flanker effect to an impairment in the focusing of spatial attention due to the presence and visibility of the co-actor.

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## Footnotes

[1] Prior studies have shown that task instructions can affect participants response coding (e.g., Dittrich & Klauer, 2012; Eder & Rothermund, 2008). Therefore, we used numbers (participant 1 and participant 2) in the instructions to assure that words like "left / right participant" did not influence subjects response coding.

[2] To acquaint subjects with the particular task, the timing in the first practice block was less speeded (3,000 ms display of the target, 3,000 ms time to respond, no-go stimuli disappeared after 1,000 ms) than in the other trials (experimental block and second practice block).

[3] We also conducted classical repeated-measure ANOVAs which led to a similar result pattern as the results reported in the main text.

[4] As described in the method section, three participants were excluded from analyses. Thus, the analyses included three "pairs" of participants that only contained one participant. In this case, the random intercept for participant and the random intercept for pairs of participants was redundant and only one was considered in the algorithm.

[5] For the statistical analysis of the joint flanker effect, Atmaca et al. (2011) and Dolk et al. (2014) compared baseline trials (average reaction times for compatible and neutral trials) with incompatible trials. Unlike them we used a comparison of compatible, neutral, and incompatible trials. Although we considered an analysis of separate compatible, neutral, and incompatible trials to be more appropriate (because analyses do not merge information and are in line with the analyses of compatible, neutral, and incompatible trials in the Simon task), we nevertheless wanted to exclude the possibility that the selection of the compatibility factor affected the results of the flanker task. For this reason, we also ran the same analyses as reported in the result section of the flanker task but with merged compatible and neutral trials. These analyses yielded the same result pattern.

[6] As can be seen in Table 1, the observed joint SCEs were quite small (3-4 ms). A look at the raw data revealed that the majority of participants (24 out of 37) showed joint SCEs

demonstrating that this small effect was stable and not only present due to large effects in a small subgroup of participants. Please also note that we consistently find smaller joint SCEs (Dittrich, Rothe & Klauer, 2012; Dittrich, Dolk, Rothe-Wulf, Prinz, & Klauer, 2013) than for example Sebanz and colleagues (e.g., Sebanz, Knoblich, & Prinz, 2003). Presumably, it is the difference between stimuli most often used by Sebanz and colleagues (a human hand pointing to the left or right) and by our group (colored circles, displayed in a horizontal row) that explains this discrepancy.

## Appendix

To identify the random effect structure, we estimated generalized mixed linear models with random effects for *participants* and *pairs of participants* for accuracy data, and mixed linear models with random effects for *participants* and *pairs of participants* for the latency data. First, we fitted a full model (am1, tm1) with a maximal random-effects structure; that is with random intercepts for participants and pairs of participants and random slopes for the factors *compatibility and condition* and all interactions thereof as a function of participants and pairs of participants. This model was compared with a "null" model (am2, tm2) in which only a random intercept for participants was implemented. Note that the null model is comparable to a repeated-measure ANOVA, typically used to analyze data in designs like the present one. If no difference was found, the null model was accepted as the final model, from which then the fixed effects were calculated and reported in the main text.

If both models differed, we tested which random slopes as a function of participants and pairs of participants were needed as well as whether a random intercept for pairs of participants was needed. Inspecting the variance estimated for the different random slopes and for the intercept of pairs of participants, we selected random slopes that appeared to be associated with the largest variances. In a second step, we therefore compared a "reduced" model with these random slopes (am3, tm3) to both the full model and the null model. The reduced model was taken as final model given a) no significant difference between the reduced model and the full model indicating that the reduced model explains the data equally well as the full model, and b) a significant difference between the reduced model and the null model indicating that additional random error components are necessary as compared to the null model. Random intercepts for pair of participants were necessary for all models indicating that pairs of participants account for variance in response behaviors.

**(I) Simon task**

*Accuracies*

| Model | *df* | *AIC* | *BIC* | *loglik* | *deviance* | $\Delta\chi^2$ | $\Delta df$ | *p* |
|---|---|---|---|---|---|---|---|---|
| am1 | 54 | 3936.6 | 4378.5 | -1914.3 | 3828.6 | | | |
| am2 | 13 | 3914.4 | 4020.8 | -1944.2 | 3888.4 | 59.77 | 41 | .03 |

→ am3: random slope for condition as a function of participants and intercept of pairs of participants.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| am1 | 54 | 3936.6 | 4378.5 | -1914.3 | 3828.6 | | | |
| am3$^{\text{final}}$ | 16 | 3865.9 | 3996.9 | -1917.0 | 3833.9 | 5.31 | 38 | .999 |
| am2 | 13 | 3914.4 | 4020.8 | -1944.2 | 3888.4 | | | |
| am3$^{\text{final}}$ | 16 | 3865.9 | 3996.9 | -1917.0 | 3833.9 | 54.47 | 3 | <.001 |

*Latencies*

| Model | *df* | *AIC* | *BIC* | *loglik* | *deviance* | $\Delta\chi^2$ | $\Delta df$ | *p* |
|---|---|---|---|---|---|---|---|---|
| tm1 | 55 | 132078 | 132487 | -65984 | 131968 | | | |
| tm2 | 14 | 132330 | 132434 | -66151 | 132302 | 334.38 | 41 | <.001 |

→ tm3: random slope for the compatibility × condition interaction as a function of participants and intercept of pairs of participants.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| tm1 | 55 | 132078 | 132487 | -65984 | 131968 | | | |
| tm3$^{\text{final}}$ | 35 | 132038 | 132299 | -65984 | 131968 | 0.43 | 20 | .999 |
| tm2 | 14 | 132330 | 132434 | -66151 | 132302 | | | |
| tm3$^{\text{final}}$ | 35 | 132038 | 132299 | -65984 | 131968 | 333.95 | 21 | <.001 |

**(II) Flanker task**

*Accuracies*

| Model | *df* | *AIC* | *BIC* | *loglik* | *deviance* | $\Delta\chi^2$ | $\Delta$*df* | *p* |
|---|---|---|---|---|---|---|---|---|
| am1 | 54 | 6818 | 7264.5 | -3355.0 | 6710 | | | |
| am2 | 13 | 6850.2 | 6957.7 | -3412.1 | 6824.2 | 114.2 | 41 | <.001 |

→ am3: random slope for condition as a function of participants and intercept of pairs of participants.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| am1 | 54 | 6818 | 7264.5 | -3355.0 | 6710 | | | |
| am3$^{final}$ | 16 | 6755 | 6887.3 | -3361.5 | 6723 | 12.95 | 38 | .999 |
| am2 | 13 | 6850.2 | 6957.7 | -3412.1 | 6824.2 | | | |
| am3$^{final}$ | 16 | 6755 | 6887.3 | -3361.5 | 6723 | 101.25 | 3 | <.001 |

*Latencies*

| Model | *df* | *AIC* | *BIC* | *loglik* | *deviance* | $\Delta\chi^2$ | $\Delta$*df* | *p* |
|---|---|---|---|---|---|---|---|---|
| tm1 | 55 | 151370 | 151785 | -75630 | 151260 | | | |
| tm2 | 14 | 151816 | 151921 | -75894 | 151788 | 527.24 | 41 | <.001 |

→ tm3: random slope for condition as a function of participants and intercept of pairs of participants.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| tm1 | 55 | 151370 | 151785 | -75630 | 151260 | | | |
| tm3$^{final}$ | 17 | 151344 | 151472 | -75655 | 151310 | 49.39 | 38 | .102 |
| tm2 | 14 | 151816 | 151921 | -75894 | 151788 | | | |
| tm3$^{final}$ | 17 | 151344 | 151472 | -75655 | 151310 | 477.85 | 3 | <.001 |

## (III) Joint analysis of Simon and flanker task

*Latencies*

| Model | *df* | *AIC* | *BIC* | *loglik* | *deviance* | $\Delta\chi^2$ | $\Delta df$ | *p* |
|---|---|---|---|---|---|---|---|---|
| tm1 | 67 | 284446 | 284994 | -142156 | 284312 | | | |
| tm2 | 26 | 285229 | 285442 | -142588 | 285177 | 865.16 | 41 | <.001 |

→ tm3: random slope for the compatibility × condition interaction as a function of participants and intercept of pairs of participants.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| tm1 | 67 | 284446 | 284994 | -142156 | 284312 | | | |
| tm3$^{final}$ | 47 | 284410 | 284795 | -142158 | 284316 | 4.62 | 20 | .999 |
| tm2 | 26 | 285229 | 285442 | -142588 | 285177 | | | |
| tm3$^{final}$ | 47 | 284410 | 284795 | -142158 | 284316 | 860.54 | 21 | <.001 |

Table 1

*Simon task: Mean reaction times (in milliseconds), mean error rates (in percent), and standard deviations for compatible, neutral, and incompatible trials as a function of condition and partition group, along with SCEs (incompatible trials - compatible trials)*

| | | Spatial Compatibility | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Compatible | | Neutral | | Incompatible | | SCE | |
| Condition | Partition group | M | SD | M | SD | M | SD | M | SD |
| | | Reaction times | | | | | | | |
| Individual go/no-go | No Partition | 332 | 39 | 328 | 38 | 336 | 40 | 4 | 15 |
| | Partition | 327 | 39 | 323 | 39 | 330 | 40 | 3 | 8 |
| Joint go/no-go | No Partition | 320 | 31 | 309 | 32 | 323 | 30 | 3 | 12 |
| | Partition | 323 | 35 | 311 | 40 | 327 | 35 | 4 | 8 |
| | | Error rates | | | | | | | |
| Individual go/no-go | No Partition | 0.8 | 1.2 | 1.3 | 1.7 | 2.1 | 2.5 | 1.3 | 2.4 |
| | Partition | 0.9 | 1.3 | 1.6 | 2.0 | 1.1 | 1.3 | 0.2 | 1.2 |
| Joint go/no-go | No Partition | 1.7 | 2.1 | 1.9 | 2.0 | 1.3 | 1.8 | -0.4 | 1.0 |
| | Partition | 1.9 | 3.5 | 2.1 | 3.7 | 2.0 | 3.3 | 0.1 | 1.0 |

Table 2

*Flanker task: Mean reaction times (in milliseconds), mean error rates (in percent), and standard deviations for compatible, neutral, and incompatible trials as a function of condition and partition group, along with compatibility effects (incompatible trials - compatible trials)*

| | | Compatibility | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Compatible | | Neutral | | Incompatible | | Flanker effect | |
| Condition | Partition group | M | SD | M | SD | M | SD | M | SD |
| | | Reaction times | | | | | | | |
| Individual go/no-go | No Partition | 381 | 55 | 376 | 62 | 388 | 49 | 7 | 18 |
| | Partition | 379 | 51 | 370 | 50 | 390 | 56 | 11 | 16 |
| Joint go/no-go | No Partition | 352 | 42 | 347 | 40 | 368 | 39 | 16 | 11 |
| | Partition | 360 | 45 | 356 | 51 | 370 | 46 | 10 | 10 |
| | | Error rates | | | | | | | |
| Individual go/no-go | No Partition | 2.1 | 2.4 | 3.5 | 3.4 | 6.7 | 4.2 | 4.6 | 2.6 |
| | Partition | 1.9 | 1.8 | 1.8 | 2.0 | 5.0 | 4.4 | 3.1 | 4.1 |
| Joint go/no-go | No Partition | 2.0 | 2.5 | 1.9 | 2.3 | 3.9 | 3.8 | 1.9 | 2.3 |
| | Partition | 0.9 | 0.8 | 1.1 | 1.2 | 2.8 | 2.6 | 1.9 | 2.3 |

**Figure Caption**

*Figure 1.* Experimental setup in the no-partition group (panel A) and in the partition group (panel B) for the individual condition (left) and the joint condition (right).

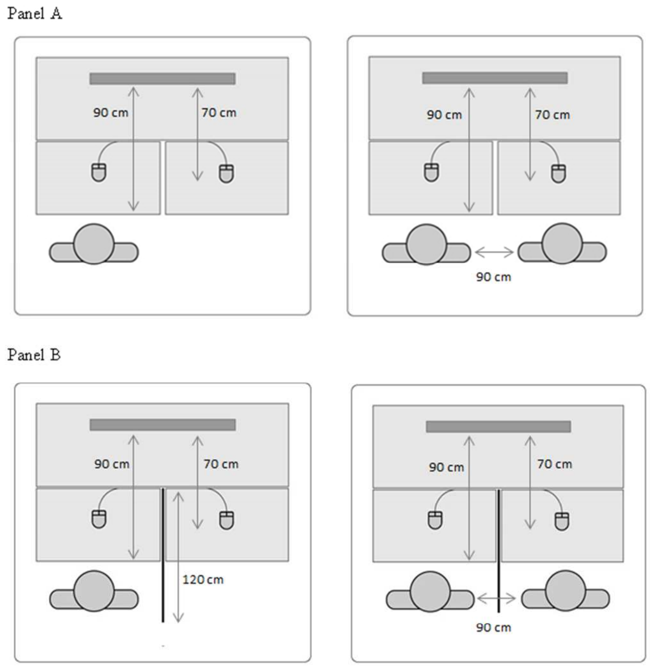


Figure 1. Experimental setup in the no-partition group (panel A) and in the partition group (panel B) for the individual condition (left) and the joint condition (right).
210x297mm (96 x 96 DPI)