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Effects of a Coactor's Focus of Attention on Task Performance

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Coactors take into account certain aspects of each other's tasks even when this is not required to perform their own task. The present experiments investigated whether the way a coactor allocates attention affects one's own attentional relation to stimuli that are attended jointly (Experiment 1), individually (Experiment 2), or in parallel (Experiments 3 and 4). Pairs of participants sitting next to each other performed a two-choice Navon task, responding to the identity of letters. Participants' tasks either required the same focus of attention (e.g., both attending to local stimulus features) or different foci of attention (e.g., one attending to local and the other to global features). Results revealed a significant slow-down of responses when participants focused on different features, suggesting that the coactor's attentional focus induced a conflict that affected the selection of one's own focus. This effect disappeared when no other person was present, and when mutual visual access to each other's stimuli was disrupted, but did not depend on a triangular relationship between participants and stimuli. Our findings extend previous research on joint attention and task corepresentation in revealing that representations of a coactor's task can include a specification of her focus of attention.

Keywords: task corepresentation, joint attention, focus of attention, Navon task

Recent findings indicate that in a shared social context people are highly sensitive to others' perceptual and intentional relations to the environment. Susceptibility to the way others look at the world is demonstrated by the alignment of gaze during conversation (Richardson & Dale, 2005; Richardson, Dale, & Kirkham, 2007) and by the efficient distribution of attention in joint visual search, where coactors consider each other's gaze direction and efficiently divide the visual scene between them (Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008). People attending to a scene together are affected by what a coactor sees and by the coactor's visuospatial perspective even when the task does not require taking into account another's perception. In a study by Samson, Apperly, Braithwaite, Andrews, and Scott (2010), for instance, participants' judgment of what they could see themselves was influenced by what an avatar present in the scene could see, indicating that the avatar's perspective was spontaneously computed. Moreover, when sitting opposite another person, people consider the other's spatial perspective, which affects how they verbally describe spatial relations between the other person and objects near this person (Tversky & Hard, 2009) and influences the way they mentally rotate jointly attended objects (Böckler, Knoblich, & Sebanz, 2011). Taken together, these studies indicate that joint attention leads people to take an interaction partner's perceptual relation to the environment into account, which may help to establish perceptual common ground (Clark, 1996; Knoblich, Butterfill, & Sebanz, 2011; Sebanz, Bekkering, & Knoblich, 2006).

It has also been demonstrated that people are receptive to others' intentional relations to the environment. When acting with or alongside another person, people tend to form representations of each other's tasks even if this is not required to succeed in their own task (Sebanz, Knoblich, & Prinz, 2005; Sebanz, Knoblich, Prinz, & Wascher, 2006; Tsai, Kuo, Jing, Hung, Tzeng, & 2006). For instance, participants showed the same pattern of results when they performed an Erikson flanker task (Eriksen & Eriksen, 1974) alone as when they carried out half of it together with another person who performed the complementary part (Atmaca, Sebanz, & Knoblich, 2011). In this two-choice task, a central stimulus requires participants to respond while it is flanked by distracter stimuli. The distracters are not linked to any response (neutral), linked to the same response as the relevant stimulus (congruent), or linked to the opposite response (incongruent). Responses typically slow down when stimuli are flanked by incongruent distracters. When the task was distributed among two actors, participants' responses slowed down when their relevant stimulus was flanked by a potential target for their coactor. It is important to note that this effect also occurred when participants merely believed to be acting with another person, but disappeared when the other's actions were controlled by a machine. This implies that (believing to be) acting with another intentional agent made participants hold representations not only of their own, but also of the other's task.

A question that has not been addressed in the joint action and joint attention literature is whether coactors also consider each other's attentional relation to the environment. In addition to specifying what the other needs to do and/or when it is a coactor's turn to respond (i.e., which stimuli require the other to act), task representations may specify other performance-related parameters, such as the way the coactor should allocate attention. For instance, consider a factory worker whose task is to inspect the packaging of screws coming down on a conveyor belt, focusing on the shape of each pack of screws. Will her performance be affected by the

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worker next to her who focuses on single screws within the package to detect odd ones? While the workers' intentional relations (task to indicate odds) and perceptual relations (visual perspectives) to the jointly attended objects are similar, the attentional relations between them and the objects differ considerably, as one of them needs to apply a more global and the other a more local focus of attention.

The aim of the present study was to investigate whether people are sensitive to another's focus of attention when performing similar tasks and holding the same spatial perspective. If this is true, then corepresentation of the attentional act to be performed by the other may lead to the modulation of one's own attention allocation. In particular, we predicted that performance in a task requiring a global or a local focus of attention should be affected by whether another person's task requires the same or a different focus of attention.

The Present Study

Investigating whether coactors take each other's attentional relation to stimuli into account requires stimuli that consist of at least two different features to which attention can be directed. In Navon tasks, stimuli are defined on two different spatial levels, on a global level and on a local level (e.g., a large letter consisting of small letters). The global and the local features can either be congruent (e.g., an S consisting of Ss) or incongruent (e.g., an S consisting of Hs). When selective attention is directed to the local features, processing is usually slowed down when global features are incongruent (Navon, 1977; Navon, 1991). Similarly, when selective attention is directed to global features, incongruent local features impair processing (Kimchi, 1992).

In the present study, we employed a joint version of a Navon task in which two participants responded to Navon stimuli appearing on a jointly attended screen (Figure 1). The critical manipulation was whether participants' tasks required them to adopt the same focus of attention (e.g., both attending to global stimulus features) or a different focus of attention (one attending to the global stimulus features and the other attending to local features). One stimulus appeared at a time, and each stimulus required the response of one of the two participants.

We predicted that participants would form a representation of the other's task that specifies the focus of attention to be applied (global or local). Thus, in addition to setting their own attentional focus in a top-down manner (Navon, 2003; Niebur, Hsiao, & Johnson, 2002; Posner & Gilbert, 1999), participants would have in mind what stimulus feature their coactor was focusing attention on. In the case where the other's focus differs from their own focus, the task representation specifying the focus to be applied by the other should lead to a top-down modulation of attentional processes and affect participants' performance (Posner & DiGirolamo, 1998; Posner & Petersen, 1990). Representing the other's task and, specifically, the attentional focus required by the other's task, can influence performance in different ways.

First, representing the other's attentional focus may interfere with selecting and maintaining one's own focus of attention when attentional foci differ. Selecting the focus required by one's own task may be delayed and applying the appropriate focus may be more difficult when the different task of the coactor is corepresented. This should result in slower responses (selection conflict hypothesis). The slow-down should be independent of whether the stimuli are congruent or incongruent since the problem of selecting and applying the appropriate focus remains regardless of whether

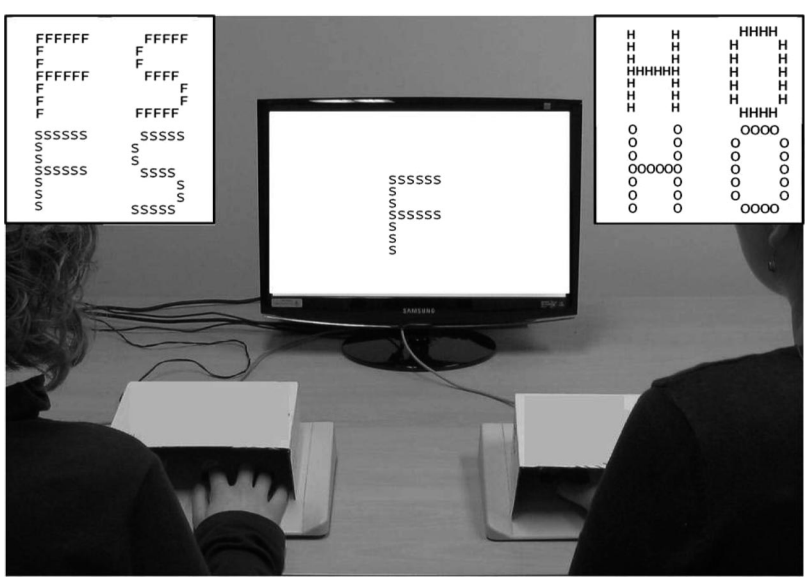

Figure 1. Experimental setting. Participants were sitting next to each other with a monitor in front of them. Both of them responded to their assigned stimuli by pressing one of two buttons with one of two fingers of their right hands. Hands were covered by boxes. In Experiment 2, only one participant was present at a time. In Experiments 3 and 4, stimuli were not presented in the center of the screen, but on the left or/and the right side of the screen.

there is a match or mismatch between the global and local letter shapes (Weissman, Roberts, Visscher, & Woldorff, 2006). Thus, the selection conflict hypothesis predicts a general slow-down when attentional foci of the two participants differ.

Alternatively, representing the other's task may lead people to adopt a focus that is biased toward their coactor's focus (biased focus hypothesis). This would imply a broadening of the focus when the other's task is to attend to the global features and, vice versa, a narrowing of the focus when the coactor's task is to attend to the local features. Specifically, the biased focus hypothesis predicts decreased control over one's own focus when attentional foci differ, which has different consequences for congruent and incongruent trials (Kerns et al., 2004). Performance on congruent trials should not be affected by the other's focus or might even be facilitated because the local and the global stimulus features are associated with the same response. Thus, processing congruent stimuli with a wider or narrower focus that enhances processing of the local or global features, respectively, should not create a response selection conflict. However, on incongruent trials responses should be slower and/or more error-prone when the other holds a different attentional focus, because in this case being biased toward the other's focus increases interference between local and global features (which require different responses). Thus, the biased focus hypothesis predicts that only responses to incongruent trials are impaired when attentional foci differ. This would be reflected in a larger difference in performance between congruent and incongruent trials when attentional foci differ compared with when they are the same.

To sum up, the selection conflict hypothesis predicts that selecting the adequate focus is hampered by the representation of the other actor's task when different foci are applied. The selection conflict hypothesis does not predict that the other's focus is adopted and applied. In contrast, the biased focus hypothesis predicts that representing the other's task leads participants to apply a focus that is shifted toward the other's focus. The selection conflict hypothesis and the biased focus hypothesis are not necessarily exclusive. In case both hypotheses hold, that is, in case participants experience a conflict as to which focus to select and additionally shift toward the focus of the other, results should reveal generally slower responses when attentional foci differ as well as an increased reaction time (RT) difference between congruent and incongruent trials.

In Navon tasks global features are considered dominant in the processing hierarchy because they are processed faster than local features and cause larger conflict in incongruent trials (Navon, 1981; for discussions of the underlying mechanism, see Kimchi, 1981; Han, Fan, Chen, & Zhou, 1997). This phenomenon, known as "global precedence," allowed us to investigate whether another's attentional focus affects performance selectively when the other's task is to attend to global features or whether attending to the dominant global features is also affected by the coactor focusing on the nondominant local features. According to the selection conflict hypothesis, the coactor's focus of attention will affect the selection of participants' own attentional focus in a top-down manner, reflecting a conflict at the level of task selection, and should therefore be independent of the dominance of global features. Accordingly, a general slow-down should be observed whenever the coactor's task requires a different attentional focus, independent of the specific focus participants hold themselves. By contrast, if participants adopt a focus that is shifted toward the other's different focus (biased focus hypothesis) a coactor's focus on global features may exert a stronger pull than a coactor's focus on local features. Accordingly, when attentional foci differ, one would expect a larger effect of the coactor's focus (impaired responses on incongruent trials) in individuals attending to local features.

Finally, if participants are not affected by their coactor's focus of attention, performance should be the same regardless of whether the coactor's task requires the same or a different focus. A congruency effect should occur in both conditions.

Experiment 1

The present experiment investigated whether participants' performance in the Navon task is affected by their coactor's focus of attention. Pairs of participants carried out a Navon task and were instructed to attend to the same stimulus features (both local or both global) or to different stimulus features (one attending to global and one to local features).

Method

Participants. Eight pairs of undergraduate students (mean age = 22.4 years; 15 women; 14 right-handed) participated in the experiment and received course credits or 10 Euro/hour for participation. For practicality reasons, the two participants in a pair were fellow students or friends.[1] All were naïve as to the purpose of the experiment, reported normal or corrected-to-normal vision, and signed informed consent prior to the experiment.

Stimuli and apparatus. Stimuli were Navon letters with large letters (size 2.2° × 3.8° visual angle) consisting of small letters (size 0.24° × 0.5° visual angle) according to a 6 × 7 matrix. Each participant responded to two different letters (Participant A to letters F and S; Participant B to letters H and O). The Navon letters were either congruent (e.g., a large F consisting of small Fs) or incongruent (e.g., a large F made of small Ss). Letters of one participant were never intermixed with letters of the other participant (e.g., there were no Ss made of Hs). Figure 1 displays the eight letters used.

Procedure. Each trial started with the presentation of a fixation cross (size 0.8° visual angle, presented in the center of the screen) for 900 ms. Subsequently, a Navon letter appeared at one of four possible locations (0.8° visual angle around the fixation cross) for 200 ms. The trial ended after a participant had responded or after 1,100 ms if no response had occurred. The intertrial interval (ITI) was 1,500 ms.

Participants were instructed to respond as fast and as accurately as possible to the appearance of their letter by pressing one of two keys with the index or middle finger of their right hand (two-choice task). All instructions about the participants' tasks, including the focus of attention to be adopted by each of them, were provided in written form on the screen. Participants were in-

[1] In a pilot experiment employing the same setup we assessed how long pairs of participants knew each other and how close they felt. No influence of familiarity and closeness on the results was revealed. Therefore, we did not collect information on familiarity and closeness in the present experiments.

structed to respond only to their letters (go-trials), and not to their coactor's letters (nogo-trials). The order of go-trials and nogo-trials was randomized and was therefore not predictable for participants. Responses were collected using two button boxes with two horizontally arranged keys. To prevent participants from observing each other's responses, carton boxes were placed above participants' right hands.

Twelve experimental blocks followed a practice block. Each block consisted of 48 trials and was succeeded by a short rest. Ahead of each block, participants were informed on the computer screen about the focus of attention they and the other needed to adopt in the subsequent block (e.g., "Participant A focuses on the large letters, Participant B focuses on the small letters"). Each participant focused on the global features (large letters) in six blocks and on the local features (small letters) in the other six blocks. In half of these blocks, the coactor's task required the same focus of attention (e.g., both attending to global features) and in the other half of these blocks the coactor's task required a different focus (e.g., one participant focusing on local features while the other attended to global features). Hence, each of the four combinations of the own (global vs. local) and the other's task (same vs. different) appeared in three blocks. The assignment of tasks changed from block to block in such a way that the four different combinations of tasks were shuffled three times in a row.

Congruency was randomized within blocks. The assignment of stimuli to responses (index vs. middle finger) was counterbalanced across subjects. Overall, the experimental session took about 50 min. After the session, participants were debriefed. During debriefing, participants were asked whether, and in what way, they thought the other's focus of attention had influenced their performance.

Data analysis. RTs of correct trials and error rates were analyzed by means of repeated measures analyses of variance (ANOVA). A $2 \times 2 \times 2$ factorial within subject design was employed on the factors Congruency (congruent vs. incongruent), Own focus of attention (global vs. local), and Other's focus of attention (same focus vs. different focus).

Two additional analyses were performed to gain a better understanding of the effects of a coactor's focus of attention. First, the factor Part of experiment was included in order to investigate whether performance changed over time with respect to any of the afore-mentioned factors. The rationale was to examine whether effects of a coactor's focus of attention are present throughout the experiment or decline/increase over time. The factors Own and Other's focus of attention were manipulated block-wise in the present experiment and each combination appeared in three blocks. Therefore, the factor Part of experiment consisted of three levels (condition appearing for the first time, for the second time, or for the third time in the experiment).

Second, an additional analysis including the factor Preceding trial (go trial vs. nogo trial) was performed. This served to investigate if any of the effects were modulated by whether the preceding trial required participants' own response (go trials) or the coactor's response (nogo trials). Specifically, we aimed at examining whether effects of a coactor's focus of attention were due to switching costs. The underlying idea is that in no-go trials, participants might mentally perform the task according to the other's instructions. This should induce costs of task switching when attentional foci differ. Accordingly, there should be larger switching costs in the different-focus condition when a go trial is preceded by a no-go trial than when a go trial is preceded by another go trial.

Results

Error rates. Mean error rate was 2.8%. A main effect of congruency was found, $F(1, 15) = 29.8$, $p < .001$, as participants responded more accurately to congruent compared with incongruent stimuli.

Reaction times. Results are depicted in Figure 2. We found a main effect of Congruency, $F(1, 15) = 59.8$, $p < .001$, reflected in faster responses to congruent compared with incongruent stimuli. Global precedence was found: Participants responded faster to the global compared with the local stimulus features, $F(1, 15) = 23.1$, $p < .001$, and the Congruency effect was larger in the local compared with the global condition, $t(15) = 4.2$, $p < .011$, two-way interaction of Own focus of attention $\times$ Congruency, $F(1, 15) = 14.9$, $p < .01$).

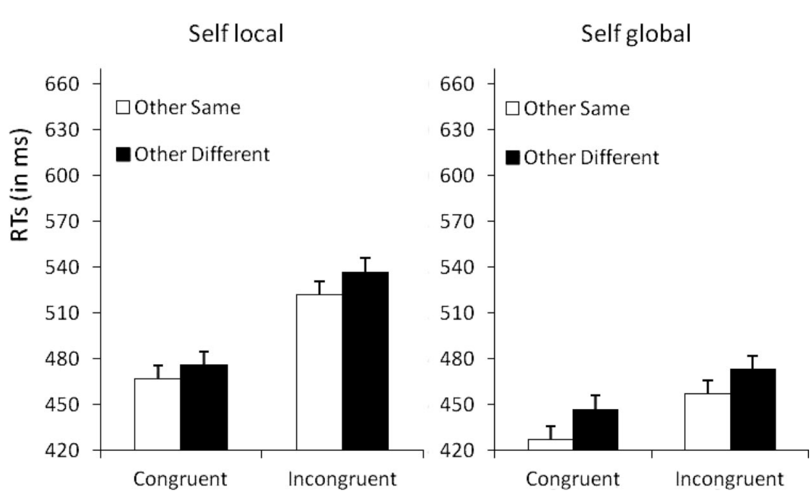

Figure 2. Reaction times in Experiment 1. Error bars display within-subject confidence intervals based on Loftus & Masson, 1994.

There was a significant main effect of Other's focus of attention, $F(1, 15) = 30.8$, $p < .001$, because of slower responses when the coactor held a different focus of attention. This effect was neither dependent on Congruency nor on the Own focus of attention, $Fs(1, 15) < 1$. Thus, the slow-down when holding different foci of attention was equally large for congruent and incongruent stimuli and for participants focusing on the local and on the global features. The three-way interaction of Congruency, Own focus of attention, and Other's focus of attention was not significant, $F(1, 15) < 1$.

Additional analyses. The effects of Congruency and Own focus of attention did not depend on Part of experiment, $Fs(1, 15) < 1$, indicating that these effects were stable across the experiment. The effect of Other's focus of attention (slow-down when other held a different focus) marginally decreased over time, reflected in a trend in the two-way interaction of Part of experiment and Other's Focus of attention, $F(1, 15) = 3.0$, $p = .08$.

The factor Preceding trial (go trial vs. nogo trial) did not interact with any of the factors, $Fs(1, 15) < 1$. Thus, all effects held independently of whether the preceding trial required the participant's response or their coactor's response.

Debriefing session. None of the participants reported having noticed that the focus of the other person influenced their performance.

Discussion

In line with the previous literature, participants were faster and more accurate when responding to congruent stimuli compared with responding to incongruent stimuli. Responses were slower to local compared with global stimulus features and the congruency effect was larger when participants attended to local features. This indicates that the current experimental setup induced global precedence.

The results revealed that the other's focus of attention influenced participants' task performance. Responses were generally slower when the coactor needed to adopt a different focus of attention compared with when the coactor's task required the same focus of attention as participants' own task. Slower RTs when the other held a different attentional focus were observed in both congruent and incongruent trials. The general effect of the other's attentional focus supports the selection conflict hypothesis and suggests that representing the other's task made it more difficult to select and maintain the focus required by one's own task.

The effect of the coactor's attentional focus was independent of participants' own focus of attention, suggesting that despite global precedence participants were not more prone to take the other's global focus into account than they were to take the other's local focus into account. Rather, whenever the coactor's tasks differed a conflict in selecting the appropriate focus seemed to occur, as suggested by the selection conflict hypothesis.

Participants were slightly more affected by their coactor's focus of attention in the beginning of the experiment, as suggested by a marginal decrease of the effect after the first blocks. This may originate in increasing familiarity with the task or in a decline in cognitive resources needed to keep in mind the other's task (Humphreys & Bedford, 2011).

Participants were affected by their coactor's attentional focus independent of whether the preceding trial was a go trial (requiring their own response) or a nogo trial (requiring the coactor's response). This suggests that the slow-down when the other held a different attentional focus was not induced by task switching costs. There was no evidence that participants covertly performed the task according to the other's instructions on no-go trials.

One could argue that the observed general slowing when the two tasks required a different focus of attention resulted from the instructions and therefore did not depend on the coactor's presence. Participants might have considered the other attentional focus even without a partner, given that the instructions equally mentioned the two different foci of attention. It is known that increasing the saliency of an alternative task through instructions can affect performance (De Houwer, Vandorpe, & Beckers, 2005; Wenke & Frensch, 2005). Therefore, one possibility is that highlighting the other's focus of attention through the instructions was sufficient to generate a conflict at the level of task selection. Even though there was no evidence that participants mentally performed the other task on no-go trials, it could be that selecting the focus required by their own task was more difficult when they had the other potential focus in mind. Experiment 2 addresses this possibility.

Experiment 2

This experiment investigated whether the instructions given in Experiment 1 are sufficient for the effect of the other's focus of attention to occur. The exact same experiment was conducted with only one participant at a time. The instructions presented on the screen were identical to the instructions in Experiment 1. Thus, the instructions also referred to another participant and prior to each block, information about participants' own and the "other's" attentional focus was provided. Participants were told that the instructions stemmed from an earlier version of this experiment where two people carried out the task. They knew, however, that they were performing the task alone. During the experiment, the same stimuli as in Experiment 1 were presented, thus, participants saw their own as well as the stimuli of the nonpresent coactor.

Method

Participants. Fourteen undergraduate students (mean age = 23.6 years; 10 women; 13 right-handed) participated in the experiment and received course credits or 10 Euro/hour for participation. All of them were naïve, reported normal or corrected-to-normal vision and signed informed consent prior to the experiment.

Results

A $2 \times 2 \times 2$ factorial within subject design was employed on the factors Congruency (congruent vs. incongruent), Own focus of attention (global vs. local), and Other's focus of attention (same focus vs. different focus).

Error rates. Mean error rate was 2%. A significant main effect of congruency was found, $F(1, 13) = 9.5$, $p < .01$, because participants responded more accurately to congruent compared with incongruent stimuli.

Reaction times. Results are depicted in Figure 3. As in Experiment 1, a main effect of Congruency was found in RTs, $F(1,$

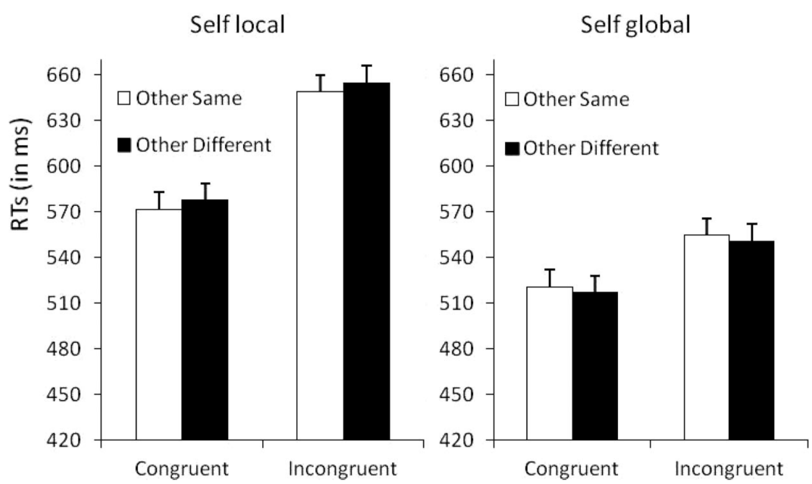

Figure 3. Reaction times in Experiment 2. Error bars display within-subject confidence intervals based on Loftus & Masson, 1994.

13) = 35.1, $p < .001$, due to faster responses on congruent compared with incongruent trials. As in Experiment 1, there was a main effect of Own focus of attention. Participants responded faster to the global compared with the local stimulus features, $F(1, 13) = 42.6$, $p < .001$, and the Congruency effect was larger in the local compared with the global condition (two-way interaction of Congruency and Own focus, $F(1, 13) = 18.1$, $p < .01$.

In contrast to Experiment 1, no effect of Other's focus of attention was found, $F(1, 13) < 1$. Thus, performance was not affected by whether the instructions mentioned that another individual should hold the same or a different focus of attention. An ANOVA comparing Experiment 1 and Experiment 2 with the between-subjects factor Experiment and the within-subject factors Congruency, Own Focus, and Other's Focus showed that the factor Experiment significantly interacted with Other's focus of attention, $F(1, 28 = 4.6$, $p < .05$, since the effect of the other's focus was present in Experiment 1, but not in Experiment 2. None of the other interactions were significant. Reaction times in Experiment 1 were significantly faster, $F(1, 28) = 10.3$, $p < .01$.

Discussion

Results of this experiment show that participants who performed the task alone did not take the attentional focus assigned to an absent coactor into account, even though they read the instructions specifying the coactor's task and perceived the stimuli for this task. This indicates that the effect of the other's focus of attention observed in Experiment 1 is a social effect in that it depends on the presence of a coacting person. Also, responses were generally slower when no other actor was present, which points toward social facilitation by a coacting person in Experiment 1 (Aiello & Douthitt, 2001). Previous research suggests that effects of social facilitation and specific effects of task corepresentation are likely independent (Atmaca et al., 2011; Welsh, Higgins, Ray, & Weeks, 2007).

What made participants consider the attentional focus of the other person when s/he was present? One possibility is that people regard what the task instructions imply for the coactor's performance given particular stimuli. In prior joint action and joint attention studies, participants typically had visual access to each other's stimuli. Visual access to the other's stimuli aligns perceptions of the coactor and may lead to the repeated activation of particular aspects of the other's task (see Wenke et al., 2011). When there is no visual access to the other's stimuli, by contrast, participants merely know about the attentional relation between the coactor and her stimuli through the instructions. Hence, an open question is whether the representation of another's attentional relation to jointly attended events requires mutual visual access to these events. Experiment 3 tested whether effects of another's focus of attention occur when the other person is present as in Experiment 1, but her or his stimuli cannot be perceived.

Experiment 3

To gain a better understanding of the mechanisms underlying the observed effect, we tested whether the slowing of RTs when coactors' foci differ would also be found when participants are instructed about each other's tasks but cannot see each other's stimuli (Figure 4). If task instructions and the presence of a coactor are sufficient to make people consider the other's task then the effect observed in Experiment 1 should occur even when participants cannot see the stimuli requiring their coactor's response. Alternatively, if performance is no longer affected by whether the coactor holds the same or a different focus of attention, this would indicate that considering another's attentional relation toward stimuli crucially depends on seeing what the other sees.

Methods

Participants. Eight naïve pairs of undergraduate students (fellow students or friends; mean age = 21.4 years; 14 women; 14 right-handed) participated in the experiment and received course credits or 10 Euro/hour for participation. All of them reported normal or corrected-to-normal vision and signed informed consent prior to the experiment.

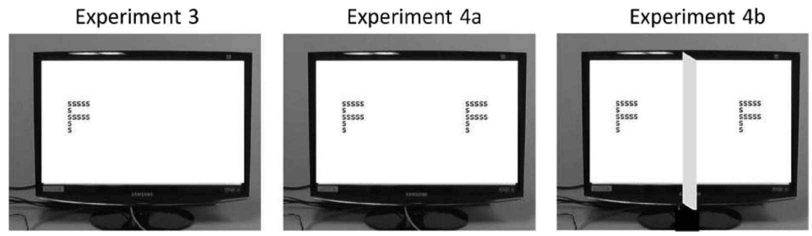

Figure 4. Stimulus display of Experiment 3 (left), Experiment 4a (middle), and Experiment 4b (right). While the coactor's stimuli were not visible in Experiment 3, they were shown in Experiment 4a. In Experiment 4b an occluder was employed to keep participants from attending to the location where the coactor's stimuli appeared.

Stimuli, apparatus, and procedure. The stimuli and procedure were the same as in Experiment 1, except that stimuli of Participant A were only shown on the left side of the screen while stimuli of Participant B were only shown on the right side of the screen. Participants did not know in advance whose stimuli would appear in a given trial, so they had to focus on their own side of the screen. Because stimulus presentation was very short and the order was randomized, participants could not attend to the center or the other's side of the screen without missing their own stimuli.

Results

A 2 × 2 × 2 factorial within subject design was used with the factors Congruency (congruent vs. incongruent), Own focus of attention (global vs. local), and Other's focus of attention (same focus vs. different focus). One participant was excluded because his error rates exceeded the average by more than 2 *SD*s.

Error rates. Mean error rate was 3.4%. A significant main effect of Congruency was found, $F(1, 14) = 20.7$, $p < .001$, because participants responded more accurately to congruent compared with incongruent stimuli.

Reaction times. Results are depicted in Figure 5. A significant main effect of Congruency was found, $F(1, 14) = 79.9$, $p < .001$, because of faster responses to congruent compared with incongruent letters. As in Experiment 1, global precedence was found: Results revealed a main effect of Own focus of attention, because participants responded faster when attending to the global compared with when attending to the local features, $F(1, 14) = 45.0$, $p < .001$. The effect of Congruency was larger in the local compared with the global condition, $t(14) = 3.5$, $p < .01$, reflected in a two-way interaction of Own focus of Attention × Congruency, $F(1, 14) = 11.9$, $p < .01$.

Contrary to Experiment 1, the main effect of Other's focus of attention was not significant, $F(1, 14) < 1$, indicating that participants responded equally fast when the other held the same and when the other held a different attentional focus. No other interactions reached significance, $Fs(1, 14) < 1$.

Discussion

As in Experiment 2, and in contrast to Experiment 1, performance in Experiment 3 was not affected by the coactor's focus of attention. This suggests that neither being informed about the coaactor's focus of attention nor acting alongside the other was not sufficient for the effect to occur. Instead, having mutual visual access to each other's stimuli seems crucial. Seeing the other's stimuli may be necessary to consider the other's focus because it provides an opportunity to relate the other's focus to visual events in the world, and it may serve to relate one's own and the other's focus. More generally, it could be that (believing that one is)

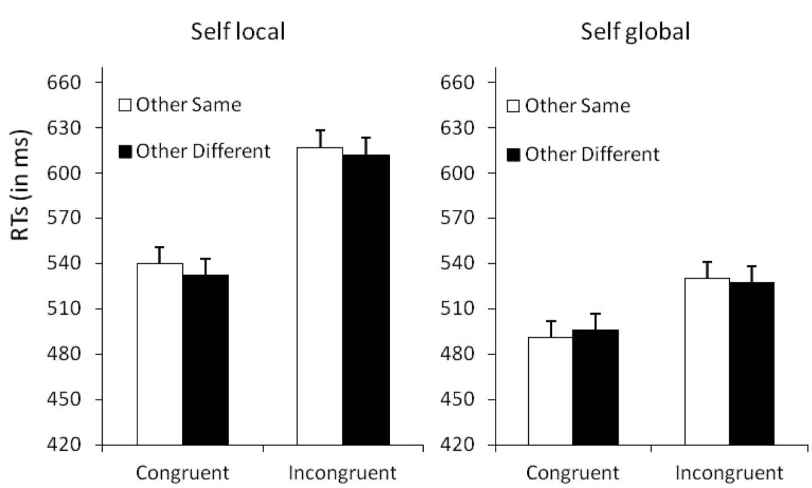

Figure 5. Reaction times in Experiment 3. Error bars display within-subject confidence intervals based on Loftus & Masson, 1994.

attending to the same stimuli is a precondition for corepresentation effects (see Wenke et al., 2011, for further discussion). This assumption needs further testing but is in line with earlier research on task corepresentation. It has been shown, for instance, that a coactor's task can affect performance even when people merely believe that the coactor is performing a particular task, as long as both coactors see or hear each other's stimuli (Atmaca et al., 2011; Ruys & Aarts, 2010; Tsai, Kuo, Hung, & Tzeng, 2008; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010).

It could be argued, though, that the setup of the present experiment did not only disrupt visual access to the coactor's stimuli, but also the triadic relation between the two coactors and the stimuli. Literature on joint attention often refers to the relation between two attendees and the jointly attended object as triangulation (Tomasello & Carpenter, 2007). Engaging in such triangular relationships can affect subsequent processing of jointly attended objects in both children (higher processing negativity; Striano, Reid, & Hoehl, 2006) and adults (action control network; Schilbach et al., 2010), and it has been argued that humans from early infancy on possess a special motivation to engage in triangular joint attention with others. By disrupting the triangular relationship between participants and the stimuli, participants may have perceived the task as not being a joint task anymore, which may have led them to ignore the other's attentional focus.

If attending jointly to one and the same stimulus (location) is a precondition for another's focus of attention to affect one's own performance, taking away the triangular relation between participants and stimuli may explain the absence of an effect of the coactor's focus in Experiment 3. To dissociate effects of the absence of triangulation from effects of the absence of visual access to each other's stimuli, we conducted a fourth experiment where triangulation was disrupted while participants were able to see their own and the other's stimuli.

Experiments 4a and 4b

These experiments investigated whether triadic joint attention is necessary for the effect observed in Experiment 1 to emerge. A similar setup as in Experiment 3 was used. However, while stimulus locations of the two participants were separate, their own stimuli and their coactor's stimuli were presented at both locations so that they could see the stimuli requiring their partner's response (Figure 4). If the absence of an effect of the coactor's focus in Experiment 3 was based on the lack of visual access to the coactor's stimuli, the effect should reappear when the other's stimuli can be seen, regardless of stimulus location. By contrast, if triangulation is a necessary precondition for an influence of the coactor's attentional focus, providing participants with separate stimulus locations should wipe out the effect of the other's focus of attention even though they can see each other's stimuli.

Method

Participants. Eight naïve pairs of undergraduate students (fellow students or friends; mean age = 20.2 years; 13 women; 13 right-handed) participated in Experiment 4a, and eight naïve pairs of undergraduate students (fellow students or friends; mean age = 22.2 years; 14 women; 16 right-handed) participated in Experiment 4b. Participants received course credits or 10 Euro/hour for participation. All of them reported normal or corrected-to-normal vision and signed informed consent prior to the experiment.

Stimuli, apparatus, and procedure. The same stimuli and procedure were applied as in Experiment 3, except that all stimuli were presented at both locations (on the left and on the right) at the same time. This provided participants with their own locations on the screen while sustaining visual access to their own and the other's stimuli. Participants were informed that they would always see the same stimuli as their coactor and could verify this during the practice block. In Experiment 4a participants were instructed to focus on their own side of the screen, but were, in principle, able to focus on stimuli depicted on the other's side. Stimulus presentation was very short, however, and triangulation was disrupted as participants could never be sure as to whether they were attending to the same location as their coactor. In Experiment 4b, a semi-transparent occluder made of frosted glass was positioned between participants (Figure 4) to prevent them from potentially attending to stimuli on the other's side of the screen. Participants in Experiment 4b could see the coactor, but they could not make out the details of the stimuli. Thus, Experiments 4a and 4b differed in regard to whether participants could potentially attend to each other's stimuli. Also, while participants in Experiment 4a could confirm throughout the experiment that the other saw the same stimuli (and knew their coactors could do so as well), participants in Experiment 4b merely believed this to be the case. If this affects the extent to which the task is conceptualized as joint, it may, in turn, modulate the representation of the other's task (Atmaca et al., 2011). Thus, if participants in the occluder condition judge the task to be individual rather than joint, effects of corepresentation of the other's task rules may decrease compared participants in the no-occluder condition.

Results

A 2 × 2 × 2 factorial within subject design was employed with the factors Congruency (congruent vs. incongruent), Own focus of attention (global vs. local), and Other's focus of attention (same focus vs. different focus). The additional factors Part of Experiment (first vs. second vs. third part) and Preceding trial (go vs. nogo) were included in separate analyses (see Experiment 1). In an ANOVA including the factor Occlusion, Experiments 4a and 4b were compared. Finally, the results of Experiments 3 and 4a/b were compared by means of ANOVAs with the within subject factors Congruency (congruent vs. incongruent), Own focus of attention (global vs. local), and Other's focus of attention (same focus vs. other focus), and the between subject factor Visual access to other's stimuli (present in Experiments 4a and 4b vs. not present in Experiment 3).

Error rates. Mean error rate was 3.1% in Experiment 4a and 2.8% in Experiment 4b. A main effect of Congruency was found, 4a: $F(1, 13) = 32.7$, $p < .001$; 4b: $F(1, 15) = 29.2$, $p < .001$, as participants responded more accurately to congruent compared with incongruent letters.

Reaction times. Results are depicted in Figure 6. Two participants of Experiment 4a were excluded because of error rates exceeding average by more than two standard deviations. A significant main effect of Congruency was found, 4a: $F(1, 13) = 126.1$, $p < .001$; 4b: $F(1, 15) = 74.8$, $p < .001$, because of faster responses to congruent compared with incongruent letters. Partic-

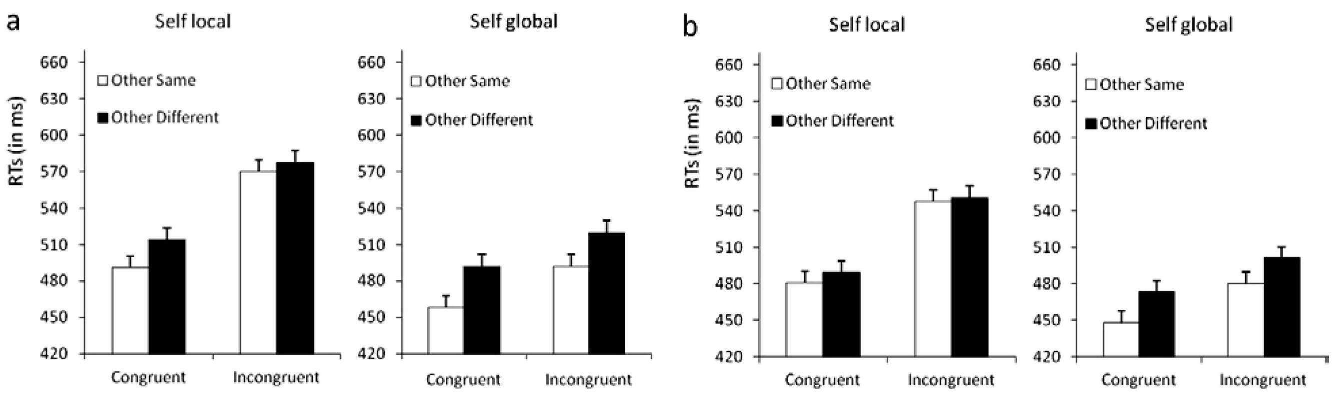

Figure 6. Reaction times in Experiments 4a (left) and 4b (right). Error bars display within-subject confidence intervals based on Loftus & Masson, 1994.

ipants responded faster when attending to the global compared with when attending to the local aspect [main effect Own focus of attention, 4a: $F(1, 13) = 47.5, p < .001$; 4b: $F(1, 15) = 28.8, p < .001$] and the effect of Congruency was larger in the local compared with the global condition, 4a: $t(13) = 2.3, p < .05$; 4b: $t(15) = 3.2, p < .01$, leading to a two-way interaction of Own focus of attention × Congruency, 4a: $F(1, 13) = 5.3, p < .05$; 4b: $F(1, 15) = 10.2, p < .01$. Thus, as in previous experiments, global precedence was found.

As in Experiment 1, there was a significant main effect of Other's focus of attention, 4a: $F(1, 13) = 8.0, p < .05$; 4b: $F(1, 15) = 5.1, p < .05$, because of faster responses when the coactor's task required the same attentional focus compared with when the coactor's task required a different attentional focus. This did not depend on Congruency, 4a and 4b: $F(1, 15) < 1$] and the Own focus of attention, 4a: $F(1, 13) < 1$; 4b: $F(1, 15) < 2.8, p > .12$. Thus, the slow-down for different attentional foci was equally large in congruent and incongruent trials and when participants focused on global and on local features. The three-way interaction of Congruency, Own focus of attention, and Other's focus of attention was not significant, 4a: $F(1, 13) = 3.0, p = .11$; 4b: $F(1, 15) < 1$. The slow-down when the other held a different attentional focus did not depend on Part of experiment, 4a: $F(1, 13) = 1.4$; 4b: $F(1, 15) = 1.7$, as it was present throughout the experiment. Similar to Experiment 1, the effect of Other's focus of attention did not depend on whether the preceding trial was a go or a nogo trial, 4a and 4b: $F(1, 15) < 1$.

Comparison of Experiments 4a and 4b. No main effect of Occlusion was revealed and none of the interactions with the factor Occlusion were significant, Fs$(1, 28) < 1.7$, ps >2.0. This suggests that none of the main effects and none of the interactions were different between Experiments 4a and 4b.

Comparison of Experiments 3 and 4a/4b. RTs were marginally faster when participants had visual access to each other's stimuli compared with when an occluder was employed, 4b: $F(1, 29) = 3.8, p = .06$. Visual access to the other's stimulus interacted significantly with Other's focus of attention, 4a: $F(1, 27) = 8.1, p < .01$; 4b: $F(1, 29) = 4.7, p < .05$. This was due to significantly slower RTs when the other's task required a different focus compared with when it required the same focus in Experiments 4a and 4b, but no such effect in Experiment 3. No other interactions reached significance.

Discussion

Participants responded more slowly when the coactor's task required a different focus of attention than when it required the same focus of attention. Even though participants were not engaged in a triangular relation including themselves, their coactor, and the stimulus, they were affected by the coactor's focus of attention. Hence, effects of a coactor's attentional focus in our task do not require triangulation. Similar to the results of Experiment 1, the slow-down induced by the other's different focus of attention was not modulated by stimulus congruency or dominance in the processing hierarchy (global precedence). The effect of the other's focus was numerically larger when participants attended to (congruent) global features, especially in Experiment 4b. This may be because congruent global trials are easiest to perform and therefore, difficulties in selecting the appropriate focus of attention induced by the representation of the other's task may be especially salient.

In line with the results of Experiment 1, the effect of the coactor's focus did not depend on the nature of the preceding trial. The extent to which the coactor's attentional focus affected performance was independent of whether the directly preceding trial required the coactor's response (no-go) or one's own response (go). This suggests that participants did not mentally adopt the other's focus on no-go trials.

The effect of the coactor's focus of attention did not decrease throughout the experiment. This finding is somewhat inconsistent with Experiment 1 where a marginal decrease of the effect over the course of the experiment was revealed. Experiments 1 and 4a/b differ as to whether participants attended to the same or to different stimulus locations. Hence, the decrease of the effect of another's attentional focus in Experiment 1 may suggest that the effect is initially increased by attending to the same stimulus (i.e., triangulation), but that this primary boost decreases as the experiment continues.

No differences between Experiments 4a and 4b were revealed in regard to effects of a coactor's focus of attention. Participants specified the coactor's focus in task corepresentation when they had visual access to the stimuli of the other, independent of whether they could (4a) or could not (4b) potentially look at each other's stimuli. Hence, the knowledge (Experiment 4a) and the belief (Experiment 4b) to have mutual visual access to identical stimuli as the coactor similarly made participants take into account how their coactor attended to those stimuli.

It is important to note that a direct comparison of Experiments 3 and 4a/b showed that participants who could process each other's stimuli were affected by each other's focus of attention (Experiments 4a and 4b), while participants without mutual visual access to each other's stimuli were not (Experiment 3). There are several ways to account for these findings. First, visual access to the coactor's stimuli on no-go trials may have increased awareness of the coactor's task and made differences in attentional focus more salient. When the coactor's stimuli could not be attended to (as in Experiment 3) there was no opportunity to relate visual events in the world to the other's focus. This interpretation is not in conflict with the observation that effects of the coactor's task occurred independently of whose turn it was on the preceding trial. Although participants most likely did not mentally adopt the other's focus on no-go trials, seeing the other's stimuli may have contributed to keeping the coactor's focus of attention in mind.

Second, it could be that mutual visual access during go-trials is critical. The conflict in selecting the appropriate focus of attention (reflected in slower RTs when the coactor's focus differs) may stem from the fact that the coactor is attending to the same stimulus with the intention of performing a task that requires a different focus of attention. This interpretation is in line with earlier findings showing differences in neural activation on go trials performed jointly versus individually (Sebanz, Rebbechi, Knoblich, Prinz, & Frith, 2007). In this study, participants showed more activation in brain areas associated with processing self-relevant information when they responded to stimuli seen by a coactor, compared with seeing the same stimuli in an individual context. This indicates that acting together can change the way self-relevant information (in the form of go-stimuli) is processed. In the present experiments, knowing that one's coactor is attending to the same stimulus may create a conflict between two task representations in the case when the two tasks differ.

Third, it is also possible that the belief (Experiment 4b) or experience (Experiment 4a) that one is perceiving the same stimuli as a coactor leads one to conceptualize the task more as a joint task and thereby constitutes a precondition for corepresenting aspects of the other's task. Seeing only one's own stimuli (as in Experiment 3) may lead people to conceptualize the task as an individual one. Future research is needed to determine whether all or only some of these factors contribute to the observed effects of a coactor's task, and what their relative contribution is.

General Discussion

The present study addressed whether and how coactors influence each other in terms of their attentional relations to events. Specifically, we investigated whether differences in coactors' attentional foci affect their performance on a perceptual task. Pairs of participants performed a Navon task together, either focusing attention on the same or on different features of Navon stimuli (local vs. global). Earlier findings show that coactors represent specific aspects of each other's tasks. We predicted that the attentional focus required by a coactor's task would be specified as part of the corepresented task and exert an effect on performance even when it is irrelevant for an individual's own task. Particularly, two different hypotheses were introduced regarding the consequences of forming an abstract representation of the other's task. The selection conflict hypothesis predicts that the representation of a coactor's attentional focus should increase the difficulty to select and to apply one's own focus of attention when attentional foci differ, resulting in slower responses to any stimulus. The biased focus hypothesis, by contrast, predicts that participants will adopt a focus that is biased toward their coactor's focus, specifically impairing responses to incongruent stimuli when attentional foci differ, and more so when the coactor is attending to global features.

In Experiment 1 participants responded more slowly when the coactor's task required a different focus of attention compared with when it required the same focus of attention. This slow-down occurred even though participants' task did not necessitate taking their coactor into account. It was equally large for congruent and incongruent stimuli and was independent of whether participants' focus was on global or local features. These findings indicate that participants represented their coactor's task in a way that entailed a specification of her or his focus of attention. When the coactor's focus of attention differed from participants' own focus, this led to a conflict in selecting the appropriate focus and increased the difficulty to apply one's own focus of attention in order to perform the task, as predicted by the selection conflict hypothesis. There were no indications that representing the other's task made participants adopt a focus that was shifted toward the other's (biased focus hypothesis).

Experiments 2, 3, and 4 further investigated the mechanisms underlying the observed effects of a coactor's focus of attention. The results of Experiment 2 rule out the possibility that receiving instructions about two different foci of attention is sufficient to cause a slowdown in responses. Single participants who received identical instructions as participants performing the task together did not show a difference in performance depending on whether the instructions mentioned one or both foci of attention. This indicates that the effect of the other's focus of attention observed in Experiment 1 is social in that it depends on the presence of a coacting person.

The results of Experiment 3 demonstrate that seeing the same stimuli is critical, as no effect of the coactor's task was observed in the absence of mutual visual access. However, triadic joint attention, where both coactors attend to the same stimulus location, is not a necessary precondition for effects of the coactor's attentional focus. In Experiments 4a and 4b, the slow down when holding different attentional foci was observed even though participants attended to different locations on the screen. This indicates that believing (4b) or knowing (4a) that a coactor perceives the same stimuli as oneself activates a representation of his or her task and induces a conflict in task selection.

The present results extend earlier findings on joint action and joint attention in showing that people are not only sensitive to a coactor's intentional relation to the environment (Sebanz, Knoblich, & Prinz, 2003; Atmaca et al., 2011) or a coactor's perceptual relation to the environment depending on gaze location (Brennan et al., 2006) or spatial perspective (Böckler et al., 2011; Samson et al., in press), but also to differences in attentional relations. The attentional relation of a coactor toward a jointly attended scene is specified as part of the other's task representation and affects how participants perform their own task. Representing tasks that involve different attentional relations (their own and the other's) participants experienced a conflict at the level of task selection, which affected attention allocation in a top-down manner. The only aspect that differed between the 'same-focus' and 'different-focus' condition was the focus required by the coactors' tasks and it is most likely that the conflict occurred once task representations with conflicting foci were activated through the stimulus presentation. The difficulty of selecting between these task representations increased the difficulty of selecting the correct focus of attention. Similarly, applying and maintaining the selected (adequate) focus in the course of stimulus processing may be more demanding when the different focus required by the other's task is represented. Further research is necessary to reveal the precise time course of the effect of a coactor's attentional focus. Electroencephalography (EEG), for instance, may be well suited to unravel the attentional and cognitive processes that underlie behavioral effects reported in the present study.

Because other aspects of the coactors' tasks (in particular, the coactors' responses, and their stimulus response mappings) were held constant, our findings demonstrate that a difference in the attentional focus to be applied by coactors is sufficient for generating a selection conflict. It is possible that other differences between tasks may also affect performance, but the mechanisms in such cases are likely of a different nature. Also, not any difference between coactors' tasks will lead to a slow-down in performance. For instance, Wenke et al. (2011) review several studies showing that when coactors' tasks differ only in terms of the required responses there is no interference between tasks.

It could be argued that the difference in RTs between trials in which both participants held the same compared with different attentional foci could as well be interpreted as a speed-up when both directed their attention to the same aspect rather than a slow-down when they attended to different aspects. The observed effect consists in a relative difference in RTs and based on the present findings we cannot exclude this possibility. Given that earlier studies on task corepresentation have predominantly found effects of interference rather than facilitation (Sebanz et al., 2003; Tsai et al., 2006), we think it is more likely that representing the other's task led to a conflict in selecting the appropriate focus when the tasks differed. However, future studies are needed to specify the relative contribution of facilitation and interference effects in the present paradigm.

The present results extend prior research on task corepresentation in an important way. So far, this research has shown that when two people perform RT tasks next to each other they form representations of each other's tasks that specify when it is the coactor's turn to act. This can be seen, for instance, in slower RTs when participants need to respond to stimuli that share features with their coactor's response (Milanese, Iani, & Rubichi, 2010; Sebanz et al., 2003; Welsh, 2009), or to stimuli containing features that are task-relevant for their coactor (Atmaca et al., 2011; Sebanz et al., 2005). As recently proposed by Wenke et al. (2011), these results can be explained by the assumption that task corepresentation (in the sense of representing which stimuli require the coactor to act) impacts performance by creating demands on processes needed to decide whose turn it is ("agent identification"). This assumption, however, cannot easily explain the present results. Representing which stimuli require the coactor to respond should have made it equally easy or difficult to decide whose turn it is regardless of the coactor's focus of attention. Instead, the present results suggest that task corepresentation can entail a more fine-grained specification of parameters required for task performance, such as the attentional focus to be applied. It remains to be seen whether other aspects of task performance such as, for instance, requirements on speed or accuracy are also taken into account by coactors.

To conclude, the present study adds to a growing literature on the interplay between social interaction and cognition by demonstrating that people are sensitive to others' attentional relations to the environment. Taking into account what others are attending to might be a means of creating (attentional) common ground that is needed to perform joint actions (Clark, 1996). While our findings do not suggest that interacting with others necessarily makes us adopt their view of the world, they do show that in choosing how to look at the world we are affected by how others look at it.

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