Psychological Research (2013) 77:240–248
DOI 10.1007/s00426-012-0425-0

ORIGINAL ARTICLE

Effects of feature integration in a hands-crossed version of the Social Simon paradigm

Roman Liepelt · Dorit Wenke · Rico Fischer

Received: 19 April 2011 / Accepted: 3 February 2012 / Published online: 17 February 2012

Abstract In previous research, hands-crossed versions of a social variant of the Simon task were used to distinguish between effector-based coding of the Social Simon effect (SSE, analogously to the standard Simon effect) or body-based coding, in which the coding of stimulus location and seating position of the participants functions as a spatial reference frame. In the present study, the analysis of the SSE with respect to previous task requirements (i.e., Simon compatibility in $N-1$) in a hands-crossed variant of the Social Simon task shows that neither type of coding provides a sole explanation of the pattern of a SSE. Instead, the data pattern seems to be explained more parsimoniously by the assumption of a strengthening of low level feature integration mechanisms in a social setting, taking repetitions and alternations of both agents' stimulus and response features into account.

R. Liepelt (✉)
Department of Psychology,
Junior Group "Neurocognition of Joint Action",
Westfälische Wilhelms-University Muenster,
Fliednerstrasse 21, 48149 Muenster, Germany
e-mail: roman.liepelt@uni-muenster.de

R. Liepelt · D. Wenke
Department of Psychology,
Max Planck Institute for Human Cognitive
and Brain Sciences, Leipzig, Germany

D. Wenke
Department of Psychology,
Humboldt University of Berlin, Berlin, Germany

R. Fischer
Department of Psychology,
Technische Universitaet Dresden, Dresden, Germany

Introduction

The ability to socially interact is fundamental for humans. For decades, the individual mind was the focus of cognitive and neuroscientific research. Instead of focusing on an isolated individual mind, recent research has made much progress in investigating the processes involved in social interaction, starting with action perception (Brass, Bekkering, Wohlschläger, & Prinz, 2000; Liepelt, von Cramon, & Brass, 2008a; Liepelt & Brass, 2010a, 2010b; Liepelt, Prinz, & Brass, 2010), internal action simulation (Gallese & Goldman, 1998), up to the understanding of action goals (Liepelt, von Cramon, & Brass, 2008b) and more high level theory of mind (Gallagher et al., 2000). In these cases, single individuals respond (offline) in a social context (Schilbach et al., 2006). Opposed to that online social interaction involves the active engagement of two agents who take turns. It has been proposed that turn taking requires a close match of both agents' action representations mediated by action simulation (Sebanz, Bekkering, & Knoblich, 2006; Sebanz & Knoblich, 2009) and action prediction (Springer et al., 2011) processes.

In line with the latter assumption new paradigms have been developed measuring joint attention (Adamson, Bakeman, & Dekner, 2004; Charman et al., 2001) and joint action under conditions of real-time interaction (Sebanz et al., 2006). Much of this research comes from the Social Simon paradigm (Sebanz, Knoblich, & Prinz, 2003), in which two persons share a "standard" Simon task (Simon, 1990; Simon, Hinrichs, & Craft, 1970). In the standard Simon task, individual participants perform spatially defined responses, such as left and right key presses, to non-spatial form attributes, like for example, a diamond or a square randomly presented on the left or right side of a monitor. Participants typically perform better when the stimulus and the response side correspond as when they do not correspond (De Jong, Liang, & Lauber, 1994; Simon & Rudell, 1967). The theory of event coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001) explains the Simon effect as a product of a binding process (Hommel, 1998) between the relevant stimulus feature (e.g., diamond or square) and the corresponding response feature (left or right), with the latter controlling the motor program. Priming occurs when the stimulus code (left–right) matches the response feature code (left–right) resulting in faster response times for corresponding and/or slower response times for non-corresponding Stimulus–Response (S–R) pairs. Usually the Simon effect is only present when responses are spatially coded so that they can be activated by spatially corresponding stimuli (Ansorge & Wühr, 2004). The standard Simon effect seems to be established by response effector coding (Wiegand & Wascher, 2007).

Sebanz et al. (2003) distributed the Simon task across two participants sitting next to each other sharing the task, so that each participant responded to only one of the stimuli by pressing one of the keys. From the participant's point of view this transforms the task into a simple go/nogo task. While performing this go/nogo version of the task alone (Sebanz et al., 2003) or together with a non-intentional agent (Tsai & Brass, 2007) did not produce a Simon effect, sharing the task with another intentional agent elicited a social Simon effect (SSE; Sebanz et al., 2003; Tsai, Kuo, Hung & Tzeng, 2008, Tsai, Kuo, Jing, Hung & Tzeng, 2006; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010).

The SSE is suggested to be elicited because two participants sharing a task do not only create a cognitive representation of their own action but they also co-represent the action of their co-actor, either through action observation or the mere knowledge about the other person's task activates another person's actions and/or task rules (Sebanz, Knoblich & Prinz, 2005; Tsai et al., 2008). Accordingly, task sharing activates the same representations and involves the same processes in each of the two actors that are usually generated to control one's own actions. This may lead to facilitation for corresponding action representations and response conflict for non-corresponding representations (Sebanz et al., 2003; Welsh, 2009).

There is recent evidence suggesting that in a simple go/nogo task the response effector is not spatially coded. Joint task performance may re-introduce spatial coding of each actor's response, because each person is responding with a spatially assigned response to one of the two left or right appearing stimuli thereby creating the SSE. Accordingly, each person may use the other person's body or the other person's response effector as a spatial reference point so that each individual's response effector is again spatially coded as left or right (Dolk et al., 2011; Guagnano, Rusconi & Umiltà, 2010).

Furthermore, recent research suggested that in a Joint go/nogo task participants may use the repetition or the switch of the stimulus location as a utility cue for predicting whether it is their own or the others turn in responding (Liepelt, Wenke, Fischer & Prinz, 2011).

Analyzing sequential trial-to-trial dependencies (e.g., Botvinick, Braver, Barch, Carter & Cohen, 2001; Fischer, Dreisbach & Goschke, 2008, 2010; Stürmer, Leuthold, Soetens, Schröter & Sommer, 2002) in a Social Simon task, Liepelt and colleagues found a positive Simon effect when the previous trial was compatible but a negative Simon effect when the previous trial was incompatible. Interestingly, this pattern of results was similar for conditions of Joint and of Individual go/nogo task performance. For the Individual go/nogo task, these effects were symmetrical and canceled each other out, resulting in a non-significant overall Simon effect. In the Joint go/nogo task, however, the effects were asymmetrical. That is, the SSE was more positive after compatible than negative after incompatible trials, thus, revealing an overall SSE. The authors concluded that the irrelevant stimulus location primed the actor or his/her response especially after compatible trials—a condition in which the last stimulus location corresponded with the actor location (seating position) and thus, response location (Liepelt et al., 2011). Based on these and other findings, Wenke et al. (2011) argued that the crucial source of the SSE may not be the co-representation of another person's task (e.g., the others specific S–R mappings) leading to response conflict for non-corresponding S–R mappings in joint task performance. Instead they argued that the SSE might concern representing when it is the other person's turn (e.g., for which stimuli the other person is responsible) leading to a conflict with respect to determining whose turn it is on a given trial (Wenke et al., 2011).

A critical limitation of most studies on the Social Simon task is, that it remains unclear what drives the SSE. As outlined, the Simon effect in the standard Simon task is based on the correspondence versus non-correspondence of the irrelevant stimulus location and the response effector location/key location (Wiegand et al., 2007). In contrast to the standard Simon task, which is performed by a single person, in the joint version of the Simon task, two persons are seated next to each other. Hence, not only the response effector but also the actor's body itself contains an additional clear spatial dimension. The body position (left and right sitting person) and the effector location (left and right responses) are strongly confounded in the typical SSE. It therefore remains unclear whether participants use a body-based coding or an effector-based coding establishing the SSE.

A recent study of Welsh (2009) addressed this particular question testing a group of participants with a two-choice Simon task and a Joint go/nogo task measuring the SSE in crossed- and uncrossed-effector conditions. The crossed-effector condition required operating the key in front of the person beside them. This setup de-confounds the body position from the effector location by keeping the person position constant while changing the effector location. First, Welsh found evidence for a standard Simon effect. He also found a SSE, which did not differ for uncrossed and crossed-effector conditions, as indicated by a lack of significance of the interaction between task (crossed vs. uncrossed) and compatibility (compatible vs. incompatible). Based on these findings, he argued for a response effector coding underlying the SSE.

However, these conclusions concerning the SSE are mainly based on a null finding (i.e., a non-significant interaction). Moreover, this study mixed crossed and uncrossed-effector conditions on the one hand, and Joint go/nogo and two-choice Simon tasks on the other hand. When mixing these conditions in the study design, the uncrossed response effector conditions and the standard two-choice Simon task may also drive the SSE found in the crossed-effector condition of the Joint go/nogo task. Therefore, from this study it does not become entirely clear whether there is a SSE in the crossed-hands condition alone, and if so—whether this effect was due to body-based coding or effector-based coding or a mixture of both.

In the present study, we aim to add further knowledge to the question whether the SSE is based on body-based coding and/or effector-based coding. For this we will also implement a crossed-effector condition in a Joint and an Individual go/nogo task. In contrast to the Welsh study, however, the present experiment will not mix crossed-effector with uncrossed-effector conditions and will leave out the standard Simon task condition. Both changes aimed at reducing potentially confounding variables. In addition and as in our previous study (Liepelt et al., 2011), we will analyze sequential trial-to-trial dependencies in both go/nogo tasks. Due to the fact that the Simon effect may be positive following compatible and negative following incompatible trials, the sequential modulation may provide an explanation in case of not observable overall Social Simon effects.

In case of *effector-based* coding, we predict an overall positive SSE. That is, the Simon effect should be more positive following compatible trials than negative following incompatible trials. In particular, in the hands-crossed version of the Simon task, in compatible trials the stimulus location corresponds with the location of the response effector but not with the location of the body. Therefore, responses will be faster under correspondence of stimulus and response effector location.

In case of *body-based* coding, we expect the opposite finding, that is, an overall negative SSE. The Simon effect should be more negative following incompatible trials than positive following compatible trials. An incompatible stimulus position is compatible with respect to the actor's body position. Incompatible trials following incompatible trials would keep the assumed link between the agent's body and the stimulus position intact, leading to facilitation.

Method

Participants

A group of 24 undergraduate students (12 males; mean age, 24.3 years; SD = 1.9) participated in this experiment. All were right-handed, had normal or corrected-to-normal vision, and were naive with regard to the hypotheses of the experiment. They were paid €7 for taking part in the experiment. Participants gave their informed consent to participate in the study, which was conducted in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki.

Apparatus and stimuli

Participants were seated in a sound-attenuated, dimly lit room. Responses were recorded with two-separated response keys placed on a table at a distance of 25 cm from each other and 25 cm away from the midline of the computer screen. All stimuli were displayed on a computer monitor in white on a black background at a constant viewing distance of 60 cm. The fixation point in the center of the screen was marked by a plus sign (0.9° × 0.9°). Stimuli consisted of squares and diamonds (1.9° × 1.9°), presented to the left or right of the fixation point with an eccentricity of 5.7° visual angle.

Procedure

The present study used an adapted version of the task by Liepelt et al. (2011). In both, the Individual-crossed and the Joint-crossed go/nogo tasks, participants responded by pressing the key contralateral to their sitting position. The person sitting on the left side responded with the right response key and the person on the right side was in charge of the left response key. Both persons responded with the index finger of their right hands to the respective stimulus. The person sitting on the right side had to respond to the square and the person on the left side had to respond to the diamond. The stimuli randomly appeared on the left or on the right of the centrally presented fixation cross. Participants were seated in front of the monitor to either the left or the right side (see Fig. 1). To keep the seating position identical in both tasks an empty chair remained in place in the individual "crossed" go/nogo task.

In the Individual-crossed and the Joint-crossed go/nogo tasks, participants responded to one of the shapes only (e.g., squares) by making a simple discrimination response. They

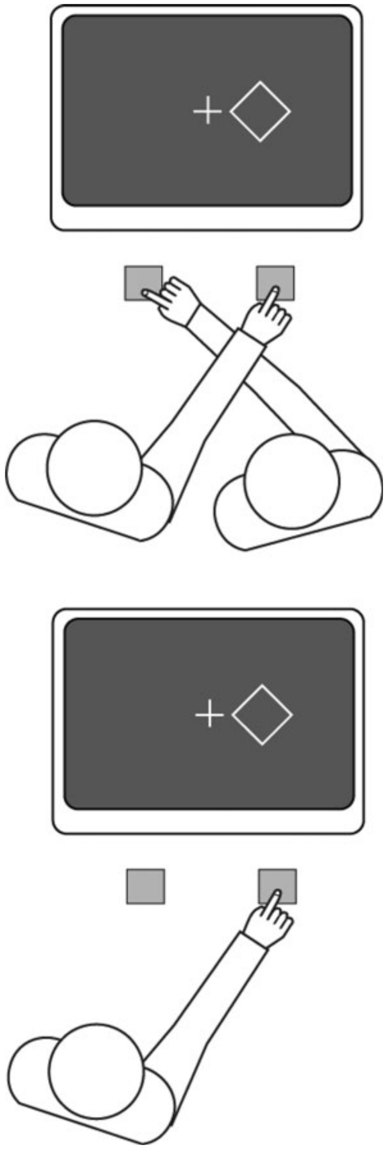

Fig. 1 Experimental setting for "crossed"-effector conditions in a Joint go/nogo task (*upper panel*) and an Individual go/nogo task (*lower panel*)

were asked to refrain from responding if the other shape (e.g., diamond) appeared. In the Joint go/nogo task, they performed the identical task sitting alongside another person who responded to the other stimulus.

Each trial began with the presentation of a fixation cross for 250 ms. The target stimulus (square or diamond) appeared together with the fixation cross for 150 ms. Responses had to be given within 1,800 ms. In the case of correct responses, the fixation cross was provided as feedback. If no response was given within 1,800 ms after stimulus onset, the feedback "zu langsam" (too slow) was shown. In the case of an incorrect response, error feedback "Fehler" (error) was provided. All forms of feedback (fixation cross, too slow, or error) were displayed for 300 ms. Following feedback, there was a constant inter-trial interval of 1,750 ms before the next trial started. In each task, participants completed five experimental blocks of 112 trials, separated by short breaks. Before each task condition, participants performed a block of 66 practice trials. The order of Individual versus Joint tasks was counter-balanced across pairs of participants.

Results

Prior to statistical RT analyses, all trials in which responses were incorrect on either the current or previous trial (<2.0%) were eliminated. Error rates were rather low over all tasks, with 1.8% in the Joint go/nogo task and 0% in the Individual go/nogo task. This reflects the ease of a simple stimulus discrimination task. Because of the low number of overall errors, error rates were not analyzed further. In addition trials faster than 150 ms or slower than 1,000 ms (<0.1%) were excluded from statistical RT analyses. The first trial in each block was also eliminated prior to analysis.

To investigate the SSE in hands-crossed conditions, mean RTs were computed as a function of setting (Individual go/nogo vs. Joint go/nogo), transition (go vs. nogo in trial$_{N-1}$), preceding compatibility (compatible vs. incompatible) and compatibility (compatible vs. incompatible) defined as the correspondence of stimulus position and response effector location.

The social Simon effect

We found no main effect of compatibility, $F(1, 23) < 1$, partial $\eta^2 = 0.01$, which indicated that irrespective of setting, response times did not differ for S–R compatibility (377 ms) and S–R incompatibility (376 ms). Responses were faster in the Joint go/nogo task (365 ms) compared to the Individual go/nogo task (388 ms), suggesting a social facilitation effect as confirmed by a main effect of setting, $F(1, 23) = 10.82$, MSe = 4823.41, $p < 0.05$, partial $\eta^2 = 0.32$.

Sequential modulation effects

We observed a significant interaction of preceding compatibility × compatibility, $F(1, 23) = 41.09$, MSe = 504.88, $p < 0.001$, partial $\eta^2 = 0.64$, showing a positive Simon effect after compatible trials and a negative Simon effect after incompatible trials, reflecting a sequential modulation of the Simon effect. This sequential modulation was more pronounced in the Joint go/nogo task than in the Individual go/nogo task (see Fig. 2), as suggested by the significant three-way interaction of setting × preceding compatibility × compatibility, $F(1, 23) = 9.99$, MSe = 157.71, $p < 0.05$, partial $\eta^2 = 0.30$.

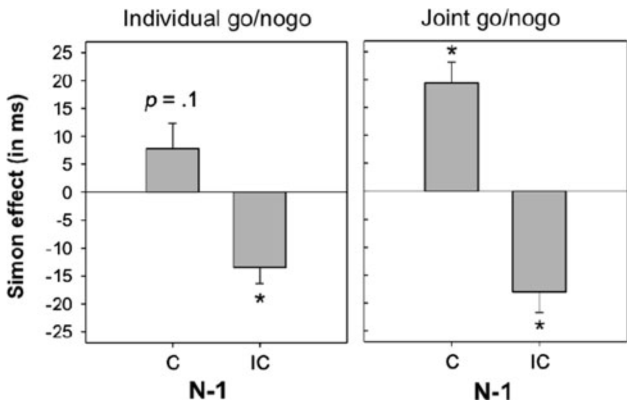

Fig. 2 Simon effect in milliseconds (ms) in trial *N*, depending on compatibility (*C*: Compatible and *IC*: Incompatible) of the previous trials for the Individual go/nogo task (*left panel*) and the Joint go/nogo task (*right panel*). $*p < 0.05$

For the Joint go/nogo task, planned comparisons showed a large positive Simon effect after Simon compatible trials (19 ms), $t(23) = 5.34$, $p < 0.001$, and a large negative Simon effect of a similar size after Simon incompatible trials (−18 ms), $t(23) = 4.79$, $p < 0.001$. For the Individual go/nogo task, we also observed a negative Simon effect after Simon incompatible trials (−14 ms), $t(23) = 4.71$, $p < 0.001$, and a positive, but a less reliable Simon effect after Simon compatible trials (8 ms), $t(23) = 1.71$, $p > 0.05$ (see Fig. 2).

A separate analysis for the individual go/nogo tasks provided no evidence of a Simon effect, $F(1, 23) = 1.27$, $p = 0.27$, partial $\eta^2 = 0.05$, but a clear sequential modulation, $F(1, 23) = 14.30$, MSe = 190.46, $p \leq 0.001$, partial $\eta^2 = 0.38$. We observed the same pattern as in the Joint go/nogo task, where we also found a sequential modulation, $F(1, 23) = 58.65$, MSe = 143.24, $p < 0.001$, partial $\eta^2 = 0.72$, without evidence for an overall Simon effect, $F(1, 23) < 1$, partial $\eta^2 = 0.003$.

We additionally compared the size of the sequential modulation between both settings for trials following Simon compatible trials in $N-1$ and following Simon incompatible trials in $N-1$, separately. Following Simon compatible trials in $N-1$, the Simon effect was significantly larger in the Joint go/nogo task (19 ms) than in the Individual go/nogo task (8 ms), $F(1, 23) = 6.06$, MSe = 134.61, $p < 0.05$, partial $\eta^2 = 0.21$. Following Simon incompatible trials in $N-1$, the reversed Simon effect for the Joint (−18 ms) and the Individual go/nogo task (−14 ms) did not differ, $F(1, 23) = 1.05$, $p = 0.32$, partial $\eta^2 = 0.04$. The social part of the SSE seems to be confined to trials following Simon compatible trials.

Transition effects

We observed a main effect of transition, $F(1, 23) = 5.91$, MSe = 798.25, $p < 0.05$, partial $\eta^2 = 0.20$, showing faster responses after go trials (373 ms) than after nogo trials (380 ms). The significant interaction of setting × transition, $F(1, 23) = 14.22$, MSe = 262.43, $p \leq 0.001$, partial $\eta^2 = 0.38$, indicated faster RTs after go trials (382 ms) than after nogo trials (395 ms) in the Individual go/nogo task, while RTs after go trials (365 ms) and nogo trials (365 ms) did not differ in the Joint go/nogo task. The sequential modulation of the Simon effect was stronger for nogo/go transitions than for go/go transitions, as indicated by a significant interaction of transition × preceding compatibility × compatibility, $F(1, 23) = 25.92$, MSe = 383.47, $p < 0.001$, partial $\eta^2 = 0.53$ (Table 1). This effect was independent of the setting in which participants performed the task (Individual vs. Joint go/nogo task), as the four factors did not interact, $F(1, 23) < 1$, partial $\eta^2 = 0.01$. No further effects reached the level of significance (all $ps > 0.05$).

Discussion

The aim of the present study was to test if body-based coding and/or effector-based coding can account for the SSE under crossed-effector conditions detached from potentially confounding uncrossed-effector or two-choice Simon task conditions. In case of effector-based coding, we predicted the Simon effect to be more positive following compatible trials than negative following incompatible trials leading to an overall positive SSE, as in the Welsh (2009) study. In case of body-based coding, the Simon effect should be more negative following incompatible trials than positive following compatible trials leading to an overall negative SSE.

In the present study, we did not find an overall SSE in the Joint go/nogo task under hands-crossed conditions. We neither found an overall positive SSE (evidence for pure effector-based coding), nor an overall negative SSE (evidence for pure body-based coding). The analysis of the sequential modulation of the SSE revealed a relatively large positive Simon effect after Simon compatible trials, as well as a relatively large negative Simon effect after Simon

Table 1 Mean reaction times (RTs) in milliseconds obtained for the two settings (Individual go/nogo, and Joint go/nogo), trial transitions (go/go and nogo/go), compatibility of the previous trial (C: Compatible and IC: Incompatible) and Simon compatibility of the current trial (C: Compatible and IC: Incompatible)

	Transition (go/go)				Transition (nogo/go)			
Previous trial	C		IC		C		IC	
Current trial	C	IC	C	IC	C	IC	C	IC
Task								
Individual	381	379	386	381	388	405	405	382
Joint	359	370	367	362	351	380	381	350

incompatible trials. This overall pattern held for both, the Individual and the Joint go/nogo task conditions, but was more pronounced in the Joint go/nogo task. In the Individual go/nogo task, we also observed no overall SSE, but a significantly negative Simon effect after incompatible trials and a small, but non-significant positive Simon effect after compatible trials. As the large negative Simon effect after incompatible trials in the Joint go/nogo task was of roughly the same size as the large positive Simon effect after compatible trials, the overall SSE was close to zero and thus, speaks against straight effector-based or body-based coding.

At first sight, the lack of an overall SSE in the Joint go/nogo task with crossed hands seems to contradict the findings by Welsh (2009) who found an overall positive SSE of similar magnitude between crossed- and uncrossed-effector conditions. However, an additional analysis[1] that included the data from our previous study with uncrossed hands (Liepelt et al., 2011) helps to reconcile our and Welsh's results: For the Individual go/nogo tasks, this analysis showed no overall SSE effect, but a sequential modulation that did not differ between crossed- and uncrossed-effector conditions. In contrast, in the Joint go/nogo tasks, we observed a significant overall SSE effect across both, crossed- and uncrossed-effector conditions that was entirely driven by a 9 ms Simon effect in the uncrossed-effector condition. This analysis basically replicates the findings of Welsh (2009) showing an overall SSE when analyzing the data for crossed- and uncrossed-effector conditions together. The present findings qualify the Welsh (2009) data by showing that the overall SSE is mainly driven by the hands-uncrossed condition and not the hands-crossed condition at least with the present task design. Thus, evidence for (pure) spatial effector coding is generally weak.

Based on our results, an explanation in terms of the underlying coding of the SSE would have to assume a flexible spatial coding mechanism in the Joint go/nogo task that switches between body-based and effector-based coordinates depending on the compatibility of the previous trial. Participants in the Joint go/nogo task condition would consider these coordinates as a spatial reference frame. The symmetrical pattern of the sequential modulation in the Joint go/nogo task suggests, however, that participants did not adopt only one spatial reference frame (effector-based or body-based). Rather, they might have switched between effector-based coding (on compatible trials) and body-based coding (on effector-incompatible trials). If so, then complete repetitions and alternations on complete matches or complete mismatches might have facilitated performance because spatial compatibility (either effector based or body based) was preserved and functioned as an agent cue. In contrast, partial matches might have slowed performance because they involved changing the spatial reference frame. Such an explanation is in line with previous observations suggesting that coding may be adapted after each response in a way that would have been beneficial in the previous trial (Botvinick, Nystrom, Fissell, Carter & Cohen, 1999, Botvinick, Cohen & Carter, 2004). According to conflict adaptation theory (Botvinick et al., 1999, 2001, 2004; Winkel et al., 2009), conflict and subsequent changes in cognitive control settings lead to performance adjustments that serve to reduce conflict in subsequent trials (Botvinick et al., 2001). Interestingly, this assumption of flexible coding can also account for the finding of an increased sequential modulation in the Joint go/nogo task compared to the Individual go/nogo task. The flexible coding account, however, is not without problems and seems at odds with previous findings. More specifically, in traditional SSE designs using uncrossed hands, we found an asymmetrical pattern of a sequential modulation (Liepelt et al., 2011). In conditions when body and effector are placed in the same spatial dimension it is not plausible to assume that participants would switch between body and effector coding. The enlarged compatibility effect following compatible trials in the Joint go/nogo task with uncrossed hands may therefore suggest that Joint task performance (with uncrossed hands) generally introduces spatial coding, and agent compatibility can be used as a cue for determining whose turn it is on a given trial. With uncrossed hands, body-based and effector-based coding works in the same direction thus, leading to an overall positive SSE.

Alternatively, the symmetrical pattern of positive versus negative SSEs, revealed by the sequence analysis resulting

[1] In order to better compare our findings with those of the Welsh (2009) study, we ran an additional analysis on the present experimental data with crossed hands including the dataset of a previous study in which another group of participants performed exactly the same task with hands uncrossed (Liepelt et al., 2011). This analysis included the factors Compatibility (Compatible vs. Incompatible), Preceding Compatibility on trial (N−1), and Group (Crossed vs. Uncrossed). The analysis was performed separately for the Individual go/nogo task and the Joint go/nogo task. For the Individual go/nogo task this analysis showed no overall SSE effect, but a sequential modulation across both groups (Crossed, Uncrossed), $F(1, 46) = 50.96$, $MSe = 132.71$, $p < 0.001$, partial $\eta^2 = 0.53$. The sequential modulation did not differ between crossed- and uncrossed-effector conditions for the Individual go/nogo tasks, $F(1, 46) < 1$, partial $\eta^2 = 0.01$. For the Joint go/nogo tasks, however, we found a significant overall SSE across both groups (Crossed, Uncrossed), $F(1, 46) = 7.26$, $MSe = 156.07$, $p < 0.05$, partial $\eta^2 = 0.14$, which was, however, entirely driven by the 9 ms Simon effect in the uncrossed-effector condition (compared to the 0 ms in the hands-crossed condition). This enlargement of the SSE in the uncrossed-effector condition compared to the crossed-effector condition was also reliable, $F(1, 46) = 5.27$, $MSe = 156.07$, $p < 0.05$, partial $\eta^2 = 0.10$. Further, we found a sequential modulation across both groups (Crossed, Uncrossed) for the Joint go/nogo tasks, $F(1, 46) = 174.44$, $MSe = 100.66$, $p < 0.001$, partial $\eta^2 = 0.79$, which did not differ between crossed- and uncrossed-effector conditions, $F(1, 46) < 1$, partial $\eta^2 = 0.002$.

in an overall concealed SSE can be fully and more parsimoniously be explained by the binding account for sequential modulation effects (Hommel, 1998). This account, explains sequential modulation patterns of the Simon (and other compatibility effects) with the assumption that codes of preceding stimulus and response features are bound in a common event file. The activation of one feature code also tends to activate the feature code that is integrated with it (Hommel, Proctor & Vu, 2004) leading to specific stimulus and response feature repetitions and alternations, that are confounded with the trial-to-trial compatibility sequence (i.e., compatible–compatible (cC), incompatible–incompatible (iI), compatible–incompatible (cI), and incompatible–compatible (iC), respectively). In a standard Simon task, the binding account predicts fast responses for cases of complete matches (e.g., repetition of stimulus identity and location), because the currently activated event file can also be used on the following trial. Fast responses are also expected for cases of complete mismatches (e.g., stimulus identity and location alternate), because the currently activated event file can be easily dismissed in the following trial. Importantly, trials with compatibility transitions of cC and iI consist of 50% complete matches and 50% complete mismatches and thus, are responded to rather fast. In contrast, partial matches (e.g., repetition of stimulus identity and alternation of stimulus location or vice versa) produce response slowing, because the currently activated event file needs to be unbound and a new event file needs to be rebound in the following trial, which takes time. Trials with compatibility transitions of cI and iC entirely consist of different partial mismatch conditions and thus, are responded to rather slow.

Importantly, this logic of feature binding can also be applied to the Social Simon task with uncrossed hands (see Liepelt et al., 2011) and also of the present design with crossed hands, which is illustrated in detail in Fig. 3. Here, go–go transitions always involve stimulus (and thus, agent) repetitions whereas nogo–go transitions always involve stimulus (and thus, agent) alternations. For both, go–go and nogo–go transitions alike, fast responses are to be expected in complete repetitions and complete switches whereas slow responses can be expected when some of the features repeat and others alternate.

Therefore, the binding mechanism, as suggested by the feature integration theory (Hommel, 1998), seems perfectly suited to explain the symmetrical positive and negative

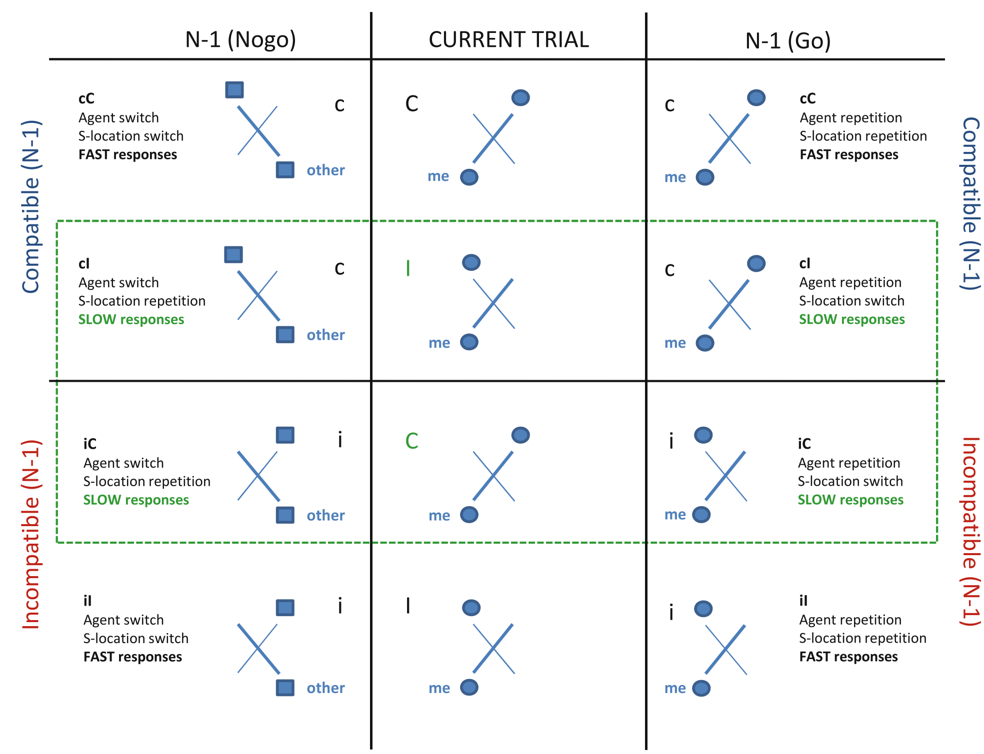

Fig. 3 Schematic illustration of seating position and stimulus location for "me" (both represented in *circles*) and "other" (both represented in *squares*) in a Joint go/nogo task. The central column represents the current go-trial (*N*). The flanking columns represent the previous trial (*N*−1) for nogo-trial (left column) or go-trial (right column) transitions. In lines, the four combinations of preceding (*N*−1) and current (*N*) stimulus–response compatibility are listed: compatible–compatible (cC), incompatible–incompatible (iI), compatible–incompatible (cI), and incompatible–compatible (iC), respectively. Note, although compatibility is coded for the response effector of the responding person, the expected fast responses for complete repetitions and complete switches versus slow responses for partial repetitions, accounts in the analogous way for a potential body-based coding of compatibility

pattern of compatibility depending on previous compatibility in the crossed-hands version of the Social Simon task. One may speculate that crucial for the SSE to emerge is whether the other stimulus shares features with the preceding stimulus and the current response, which are integrated in a common event file.

In addition, feature integration theory can also perfectly account for the finding of a pronounced sequential modulation of the SSE in the Joint compared to the Individual go/nogo task. That is, the social setting might simply strengthen the binding between (irrelevant) stimulus position and actor (me vs. you as opposed to me vs. not me). This strengthening of binding might be induced by the additional demand in the Joint go/nogo task to discriminate between "my turn"/"your turn" compared to the Individual go/nogo task that merely requires to distinguish between "my turn or not". This additional requirement might result in an enhanced benefit in cases of complete repetitions (with repetition of stimulus position signaling that "it is my/the other's turn again") and complete alternations (with stimulus position change functioning as a cue for signaling a change in whose turn it is), or in enhanced costs when only part of the information or turn taking requirements change.

Highlighting the role of low level feature integration mechanisms as a much more parsimonious explanation of the present result pattern than a flexible coding assumption, gives rise to another interesting speculation. Even though the basic mechanism underlying the SSE may be rather low level, such as the proposed feature integration mechanism, differences in the amount of the perceived socialness (human vs. non-human co-actor, Tsai et al., 2007) and the interpersonal relationship (positive vs. negative relation, Hommel, Colzato, & van den Wildenberg, 2009) would modulate the size of the SSE when the individuated event files of both actors interact according to the relationship between actor and co-actor (Hommel, Colzato, & van den Wildenberg, 2009). Clearly, further research is needed along these lines.

Conclusion

Taken together, the present findings seem to be in line with the recently proposed *actor* co-representation account (Wenke et al., 2011). In the Social Simon task, we may not co-represent the other agent's task in terms of the other's specific S–R mappings, but the other agent's responsibility for a complementary task share, i.e., when the other agent has to respond, and where the other agent's body or effector is located relative to our own response effector (e.g., Guagnano et al., 2010). Finally, following Liepelt et al. (2011), the present findings further demonstrate the possibility that a detailed analysis of trial-to-trial dependencies in the Social Simon task may allow a deeper insight in the underlying processes of the SSE that otherwise may have remained concealed by a null effect. Further research should apply the present kind of analysis when testing the social factors that modulate the size of the SSE.

Acknowledgments The present research was supported by a grant from the German Research Foundation awarded to R.L. (DFG LI 2115/1-1). The authors wish to thank Julia Haupt for help with data acquisition, Marco Steinhauser and Timothy N. Welsh for their helpful comments on a previous version of this article.

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